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ORGANIC CONTAMINANTS IN THE
GREAT LAKES 1986-1990.

prepared by

Serge L'Italien

Direction
générale
des eaux
intérieures
et des terres

Région de
l'Ontario

Canada

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**ENVIRONMENTAL QUALITY BRANCH
INLAND WATERS DIRECTORATE
ONTARIO REGION
BURLINGTON, ONTARIO**

DECEMBER 1993

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ABSTRACT

Large-volume surface water samples have been collected in the spring from 1986-1990 throughout the Great Lakes. Mean lakewide concentrations have been determined for organochlorine pesticides, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs) and chlorobenzenes using the Maximum Likelihood Estimation method (MLE). The objectives of this study were to assess temporal changes on a lake-by-lake basis and differences between lakes, to identify input areas and to compare concentrations to water quality criteria. Alpha-BHC, lindane, heptachlor-epoxide and dieldrin were ubiquitous. Generally, the concentrations of organochlorine pesticides decreased from 1986 to 1990, the highest overall being measured in Lake Ontario. Localized concentrations identified areas as sources of some organochlorine pesticides to Lake Ontario: Niagara and Oswego Rivers; Black River Bay; Port Weller; Hamilton, Toronto and Kingston Harbours; and the Welland Canal. The Maumee, Detroit and Sandusky Rivers were releasing organochlorines and PCBs into Lake Erie. PCBs were widespread from 1986 to 1990. Saginaw and Georgian Bays, as well as Lake Michigan, contributed PCBs to Lake Huron. The Niagara River and the Black River Bay, where maximum PCB concentrations were measured, were major sources of PCBs to Lake Ontario, as well as Hamilton Harbour. Total PCB concentrations were higher in the Lower Lakes than in the Upper Lakes. Total dichlorobenzene concentrations were higher in the Lower Lakes, Lake Ontario's being the highest overall. Hamilton Harbour's total dichlorobenzenes were ten times higher than Lake Ontario's. Oswego and Niagara Rivers, and Hamilton Harbour were sources of chlorobenzenes to Lake Ontario. The Detroit River was contributing dichlorobenzenes to Lake Erie. The maximum PAH concentrations were reported in Hamilton Harbour. The Niagara and Oswego Rivers, Black River Bay, Hamilton and Toronto Harbours were sources of PAHs to Lake Ontario. Exceedences of water quality criteria were limited to nearshore regions influenced by industrial activities and populated areas.

1. INTRODUCTION

The Inland Waters Directorate, Ontario Region of Environment Canada, is committed by the 1987 Amendment of the 1978 Great Lakes Water Quality Agreement (GLWQA) to monitor the international waters of the Great Lakes between Canada and the United States. The International Joint Commission supervises the commitment of both countries to restore and maintain the chemical, physical and biological integrity of the Great Lakes Basin Ecosystem. Growing concern has been expressed for persistent toxic contaminants in the lakes, especially organic compounds. The concentrations of most of these compounds in the water column are in the ng/L range (Allan and Ball, 1990; Environment Canada, Fisheries and Oceans, and Health and Welfare Canada, 1991; Strachan and Edwards, 1984; Oliver, 1984; Oliver and Niimi, 1988). Several studies have been undertaken using different large-volume extraction techniques, which have proven to produce comparable results.

Organochlorine pesticides and PCBs were studied in 1981 in the Lower Great Lakes Region (McCrea *et al.*, 1985). Water samples of approximately 8,000 L were passed through a Westfalia centrifuge to separate the particulate and dissolved phases. The centrifuge effluents (200 L) were transferred *in situ* to an aqueous phase liquid-liquid extractor (APLE). Organochlorine contaminants were analyzed in a 1983 study in which whole water samples (36L) were collected at 14 stations and then extracted with the APLE (Biberhofer and Stevens, 1987). In 1987, large water samples (200 L) collected in the Toronto waterfront were processed through an APLE extractor (Eli Eco Laboratories Inc., unpublished). The APLE extractor was used on water samples (180 L) collected in the 1988 Bay of Quinte Toxics Contaminants Survey (Poulton, 1990).

A study was carried out from 1988 to 1989 investigating PCBs and PAHs in whole water samples in Hamilton Harbour using the "Pepsi can" technique (Fox, 1986 and 1990). Samples were collected and stored in 20 or 40 L stainless pressure containers (a.k.a. Spartanburgh). In the laboratory, water samples from the storage cans were pressure-filtered with nitrogen into an extraction container at 15 psi through 1.0 μm glass fiber filters. The filtrate was extracted in dichloromethane while thorough mixing of the contents was ensured by a mixer.

The Seastar system with the XAD resin was used for a study undertaken between 1988 and 1991 in the Cornwall-Massena area (Biberhofer, Backus, Comba, and Kaiser, poster presented at SETAC in 1992) and in studies of Lake Ontario's nepheloid layer (Backus *et al.*, 1992; Mudroch, 1991). This system uses a solid-solid extraction technique that is performed in laboratory. Whole water samples were passed through a Westfalia centrifuge, with limited success. Optional installation of a CD 18 filter on the Seastar system between the pump and the resin would enhance separation of

the particulate and dissolved fractions.

Large-volume extractors developed by Goulden and Anthony have enabled one to achieve detection limits in the pg/L range (Goulden and Anthony, 1985). The Niagara River Upstream/Downstream Monitoring Program (Niagara River Data Interpretation Group, 1988, 1989, 1990 and 1992) and the St. Lawrence River Monitoring Program are using this liquid-liquid extraction technique. Sediments are separated from the whole water with the use of a Westfalia centrifuge. The clarified effluent is then processed in situ through a Goulden extractor.

The objective of this study is to give an overview of the spatial and temporal distribution of the following groups of compounds in the Great Lakes: organochlorine pesticides, polychlorinated biphenyls (PCBs), chlorobenzenes and polynuclear aromatic hydrocarbons (PAHs). This paper updates the results reported by Stevens and Neilson in 1989. It enables us to discuss inter-annual changes on a lake-by-lake basis and differences between lakes. Identification of major input areas will draw attention to potential problems. Comparison to water quality criteria leads to a prioritization of contaminants essential to the implementation of management plans such as the Lake Ontario Toxics Management Plan (converting to a Lakewide Management Plan) or the Lake Superior Initiative. The reproducibility of the overall data acquisition process is also assessed through statistical testing of the duplicate samples.

2. MATERIALS AND METHODS

2.1 Station location

The location of the stations monitored for the organic contaminants studies are given for each of the lakes, for each of the years when they were carried out (APPENDIX A, Fig. 1 to 4).

2.2 Sampling procedures

The concentrations of the organic compounds monitored in the open waters are of the order of ng/L (ppt). Large volume samples are therefore collected to enable analytical detection. The sampling procedures were identical for the 1986, 1987, 1988 and 1990 organic contaminants studies. Using a March submersible pump with teflon-lined, stainless-steel braided tubing, water samples were collected in 22 L glass carboys. All samples were taken at a 1 m depth from the windward side of the ship. For all studies, 37 L of water were collected from the Lower Lakes (Erie and Ontario), and 55 L from the Upper Lakes (Superior and Huron, including Georgian Bay).

1986

On the annual spring surveillance cruises on lakes Ontario (April 14-18), Huron and Georgian Bay (May 5-12), Superior (May 12-19) and Erie (April 28 - May 2), whole water was collected from a total of 96 stations. Duplicate whole and centrifuged water samples were taken at 9 of these stations (Neilson and Stevens, 1988; Neilson et al., 1988). The water was passed through a Westfalia centrifuge which was set at a flow rate of 6 L/min.

1987

On the annual spring cruises on lakes Huron (May 4-11) and Superior (May 12-21), whole water was collected from a total of 46 stations. Duplicate samples were taken in those lakes at 7 and 5 stations, respectively.

1988

On the annual spring cruises on lakes Ontario (April 5-9) and Huron (May 2-10), whole water was collected from a total of 63 stations, including 5 stations in Hamilton Harbour. Duplicate samples were taken at 4 stations on each lake. Sampling on Lake Huron focused on very specific areas: Saginaw Bay, interface with Lake Michigan, and in Georgian Bay. This data was not intended to represent lakewide conditions, but localized concentrations. The samples collected at 5 stations in Hamilton Harbour also reflect local conditions.

1990

On the annual spring cruise on Lake Ontario (April 2-7), whole water samples were collected from a total of 47 stations, including 5 stations in Hamilton Harbour. Duplicate samples were taken at 4 stations.

2.3 Sample processing and analysis

The whole water samples were extracted onboard vessel into dichloromethane immediately upon collection using the large-volume continuous-flow Goulden extractor (Goulden, 1985). The extracts were stored in the dark at 4°C and submitted to the National Laboratory for Environmental Testing (NLET, Burlington, Ontario) and analyzed as detailed in Stevens and Neilson (1989). Field procedures for PAHs were identical, and similar analytical methods were used with the exception that the extracts were not re-concentrated in iso-octane, but were concentrated and analyzed by gas chromatography (NLET, Analytical Methods, in prep.).

The detection limits for this study are given in Table 1.

2.4 Validation of data

2.4.1 Surrogate recoveries

In 1986, five surrogates were added to the samples to quantify the variability at different steps in the process of extraction and analysis (Neilson and Stevens, 1988; Stevens and Neilson, 1989). The surrogates for Fraction A were 1,3-dibromobenzene (DBB), 1,3,5-tribromobenzene (TBB), 1,2,4,5-tetrabromobenzene (TeBB) and 2,3,5,6-tetrabromobiphenyl (TCBP), and for Fraction B, endrin ketone (EK). In 1987 and 1988, one surrogate eluting in Fraction B was added: delta-BHC (δ -BHC). In 1990, 2,3,5,6-tetrabromobiphenyl (TCBP) was discontinued because it caused interference with aldrin.

The mean and standard deviation of the percent recoveries were calculated to define a confidence interval of valid recoveries. As was done for the interpretation of the 1986 data (Neilson and Stevens, 1988), the confidence interval was defined as the mean (all samples, including duplicates) plus or minus 2 standard deviations. For each station, when the surrogate recoveries were outside the interval, the parameters that coeluted in that Fraction were deleted.

Table 1 Detection limits for organic compounds analysis (ng/L) from 1986 to 1990.

CODE	COMPOUND	DETECTION LIMIT
BHD	Alpha-BHC	0.30
LIN	Lindane (Gamma-BHC)	0.14
HEP	Heptachlor	0.03
ALD	Aldrin	0.01
HEX	Heptachlor-Epoxide	0.02
CHC	Gamma-Chlordane	0.03
CHA	Alpha-Chlordane	0.06
EMX	Alpha-Endosulfan	0.02
DDE	p,p'-DDE	0.06
DEO	Dieldrin	0.05
END	Endrin	0.03
DDO	o,p'-DDT	0.09
TDP	p,p'-TDE	0.10
DDP	p,p'-DDT	0.10
EMY	Beta-Endosulfan	0.06
MIR	Mirex	0.04
MEY	Methoxychlor	0.22
PCB	Total Polychlorinated Biphenyls	0.81
DCB13	1,3-Dichlorobenzene	0.30
DCB14	1,4-Dichlorobenzene	0.51
DCB12	1,2-Dichlorobenzene	0.58
TOTDCB	Total Dichlorobenzenes	0.30
TCB135	1,3,5-Trichlorobenzene	0.02
TCB124	1,2,4-Trichlorobenzene	0.24
TCB123	1,2,3-Trichlorobenzene	0.09
TECB	1,2,3,4-Tetrachlorobenzene	0.09
QCB	Pentachlorobenzene	0.04
HCB	Hexachlorobenzene	0.04
FLO	Fluoranthene*	0.35
B(B/K)FL	Benzo(B/K) Fluoranthene	0.49
BFJ	Benzo (A) Pyrene	0.46
IDPY	Indeno (123-CD) Pyrene	0.26
BFH	Benzo (GHI) Perylene	0.23
INDENE	Indene	0.2
THNP1234	1,2,3,4-Tetrahydronaphthalene	0.25
MTHNP1	Methylnaphthalene-1	0.28
MTHNP2	Methylnaphthalene-2	0.26
BCLNPHT	2-Chloronaphthalene	0.47
ACENPHT	Acenaphthene	0.3
ACENPHY	Acenaphthylene	0.19
FLUORE	Fluorene	0.19
PHNAN	Phenanthrene	0.13
PYRENE	Pyrene	0.32

* : Only PAH analyzed in 1987; others analyzed in 1988 and 1990.

2.4.2 Maximum Likelihood Estimation

Due partly to non-detects and non-randomness of station siting, the data were not normally distributed. Assuming that the data followed a log-normal distribution, the Maximum Likelihood Estimation method to calculate mean and 90% confidence intervals was used for all chemicals with three or more measured values above the detection limit (Data Interpretation Group River Monitoring Committee, 1992 and El-Shaarawi, 1989).

While using the MLE method, concentrations influenced by local sources were separated from the open-lake measurements and lakewide means were computed. In the Lake Ontario 1986, 1988 and 1990 studies, data from stations # 8 (Toronto Harbour), # 76 and 97 (Black River Bay), # 86 (Niagara River mouth), # 71 (Oswego River mouth), and # 104, 105, 106, 107 and 108 (Hamilton Harbour) were not included in the estimation of the lakewide means. In the Lake Huron 1986 and 1987 studies, results from station # 101 (Saginaw Bay) were also excluded from the calculation of the means.

The 1988 Lake Huron study was representative of local conditions. Stations were pooled as follows before the MLE method was used: # 12, 14, 62, 66 and 67 (Lake Huron), # 17, 20, 23, 94, 95, 96, 100, 101 (Saginaw Bay and interface with Lake Huron), # 63, 64, 65, 102, 103 (interface with Lake Michigan), # 27, 43, 44 (Georgian Bay) and # 4 (Nottawasaga Bay).

In some cases, the MLE method would give results that were not realistic. For example, when the number of observations was low and the actual concentrations were much higher than the detection limit, means were overestimated. In order to obtain an unbiased estimation of the mean, a second version of the MLE was used for the computation. Confidence intervals became unavailable then.

2.4.3 Reproducibility analysis

Duplication of samples is used to evaluate the reproducibility of the overall data acquisition procedure, including sampling and analysis. Due to the non-normality of the data distribution, the Wilcoxon signed-rank test was used to assess the reproducibility of the analytical methods on duplicate samples taken at random stations (Snedecor and Cochran, 1972). The SYSTAT software package was used to perform this test (Wilkinson, 1988). The test showed significant reproducibility of the methods except for PCBs, and indicated poor reproducibility for fluoranthene and 1,3-dichlorobenzene.

3. RESULTS

The analytical results for organochlorine pesticides (OCs), total polychlorinated biphenyls (PCBs), chlorobenzenes (CBs) and polynuclear aromatic hydrocarbons (PAHs) are detailed in Appendix B. In the case of duplicate samples, the first result reported was used for the calculation of means (MLE), as long as the surrogate recovery was valid. The second result was simply dropped. Appendix C contains the spatial distribution maps of some of the organic contaminants monitored.

3.1 Surrogate recoveries

Appendix D reports all surrogate recovery results from 1986-1990. Approximately 11% (26/242) of results eluting in Fraction A were deleted, and 0.06% (14/242) in Fraction B (Fig.1). The rejected results are marked with an "R".

In 1986, the highest variability ($28.7 < \text{C.V.} < 34.6$) was observed for Lake Erie where five stations (# 214, 219, 220, 223 and 226) showed recoveries generally lower than 60% for the Fraction A surrogates. The chlorobenzene results for these locations are probably biased low. The Georgian Bay recovery data were very high, suggesting a possible high bias (Stevens and Neilson, 1989).

In 1987, the variability amongst the surrogate recovery data for Lake Superior was low ($7.9 < \text{C.V.} < 16.6$). However, results for parameters coeluting in Fraction A were deleted at 5 stations (# 2, 31, 52, 101 and 139), and at 2 stations (# 177 and 196) for those eluting in Fraction B. Surrogate data for Lake Superior, Lake Huron and Georgian Bay were generally good ($77.7 < \text{Mean} < 141.6$).

The 1988 Lake Ontario surrogate recoveries exceeded 200% at 2 stations (# 49 and 80) for δ -BHC and the results for the parameters coeluting in Fraction B were deleted, as well as those recorded at station # 102. The variability of the recoveries was low ($13.1 < \text{C.V.} < 18.1$) except for δ -BHC (C.V. = 32.3). The surrogate recovery data for Lake Huron showed a low variability ($10.6 < \text{C.V.} < 15.4$), with an overall mean between 76.2% and 103.3%.

For the 1990 Lake Ontario study, the variability for the recoveries eluting in Fraction B ($\text{C.V.} > 37\%$) is the highest overall (1986-1990). At station # 104, the recoveries exceeded 300%. Results for parameters eluting in Fraction A were deleted at 7 stations (# 5, 10, 11, 73, 86, 97 and 108), although the variability of recovery was relatively low (C.V. = 20) and the overall mean was between 78% and 114%.

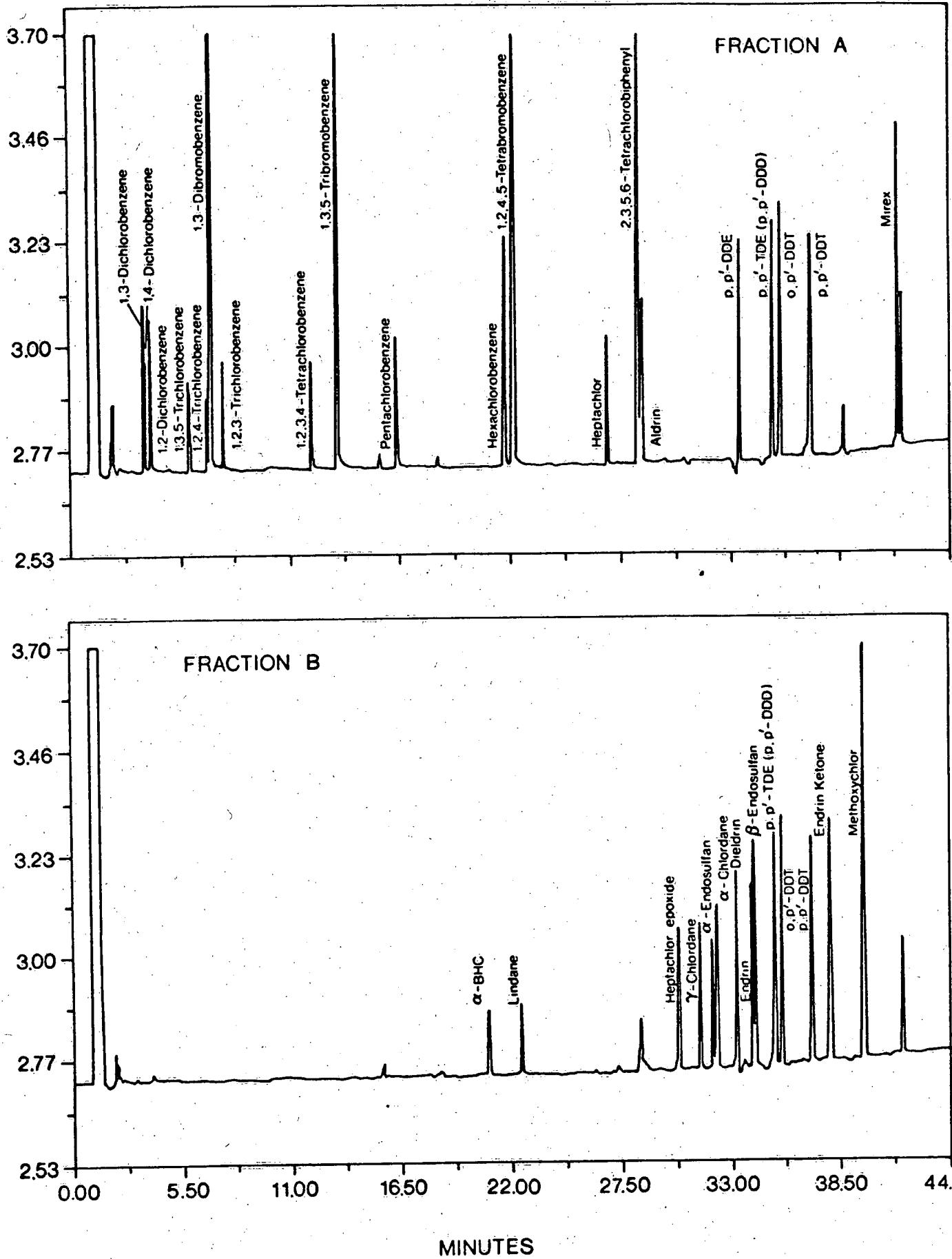


Fig. 1. Capillary column gas chromatograph/electronic detection capture (GC/EDC) trace of Fraction A and B standards.

3.2 Lake Superior

Table 2 summarizes Lake Superior's 1986 and 1987 organic contaminants studies, as computed by the MLE method.

3.2.1 Organochlorine pesticides

In 1986 and 1987, alpha-BHC, lindane (gamma-BHC), heptachlor-epoxide and dieldrin were detected at most of the locations. The BHC isomers recorded the highest concentrations. The lakewide alpha-BHC mean concentration has doubled from 1986 to 1987.

In 1986, gamma-chlordane was detected near Superior, Duluth and Thunder Bay (stations # 139, 220 and 221), and again near Superior in 1987.

3.2.2 Total polychlorinated biphenyls

Total PCB concentrations were below detection limit (0.81 ng/L) in 1986. In 1987, total PCBs averaged 0.75 ng/L and were detected at a third (7/21) of the stations monitored.

3.2.3 Chlorobenzenes

In 1986 and 1987, dichlorobenzenes were widespread. Total lakewide mean concentrations varied between 0.55 and 0.59 ng/L.

In 1986, 1,2,4-trichlorobenzene was detected in the eastern central basin and near Marquette (stations # 23, 51 and 80). In 1987, it was observed near Superior (station # 220) and again in the open waters of the eastern basin (station # 80).

Hexachlorobenzene was detected at station # 23 in 1986.

3.2.4 Polynuclear aromatic hydrocarbons

Fluoranthene was detected at 13 of the 21 stations sampled in 1987 and recorded a mean concentration of 0.58 ng/L.

Table 2. Lake Superior 1986 and 1987 organic contaminants studies.

Parameter	Detection Limits	Values >P.D.L.	No. Samples	Mean Conc. (ng/l)	Standard Deviation	C.I. Conc.. (ng/l) Minimum	Maximum
1986							
Alpha-BHC	.300	17	17	7.803	.3196	7.296	8.345
Lindane	.140	17	17	1.078	.3177E-01	1.028	1.132
Heptachlor-Epoxide	.200E-01	17	17	.1217	.4988E-02	.1138	.1302
Gamma-Chlordane	.300E-01	3	17	.1992E-01	.5269E-02	.1247E-01	.2969E-01
Dieledrin	.500E-01	17	17	.2811	.1072E-01	.2640	.2992
Total PCBs	.300	16	17	.5880	.5159E-01	.5073	.6764
124-TCB	.240	3	17	.1562	.4676E-01	.9139E-01	.2440
1987							
Alpha-BHC	.300	19	21	14.62	4.914	7.962	23.98
Lindane	.140	19	21	1.031	.1629	.7862	1.320
Heptachlor-Epoxide	.200E-01	19	21	.8080E-01	.9400E-02	.6631E-01	.9712E-01
Dieledrin	.500E-01	19	21	.2570	.3416E-01	.2048	.3168
Total PCBs	.810	7	21	.7484	.6242E-01	.6505	.8551
Total DCBs	.300	16	21	.5538	.6075E-01	.4599	.6590
Fluoranthene	.350	13	21	.5822	.1114	.4177	.7824

3.3 Lake Huron and Georgian Bay

Mean concentrations for Lake Huron's and Georgian Bay's 1986, 1987 and 1988 organic contaminant studies are summarized in Tables 3 and 4. Table 5 presents 1988's results for Saginaw Bay and the interface with Lake Michigan (Straits of Mackinac or connecting channels). The 1986 and 1987 data reflect lakewide concentrations, while localized conditions are represented by the 1988 survey.

3.3.1 Organochlorine pesticides

Alpha-BHC, lindane, heptachlor-epoxide, and dieldrin were detected at most locations in Lake Huron and Georgian Bay throughout the study period (1986-1988). Mean lakewide levels of alpha-BHC generally decreased from 1986 to 1988 (Fig. 2).

The maximum concentrations of lindane in Lake Huron and Georgian Bay were reported in 1986 (Fig. 3). They dropped in 1987 only to increase in 1988. At the interface with Lake Michigan, mean lindane concentrations were estimated at 0.35 ng/L while they were 0.45 ng/L in the Saginaw Bay.

From 1986 to 1988, mean dieldrin concentrations in Lake Huron were higher than those in Georgian Bay (Fig. 4). In 1988, they were estimated at 0.42 ng/L at the interface with Lake Michigan and at 0.24 ng/L in Saginaw Bay.

Endrin was detected in 1988 only. It averaged 0.05 ng/L in Georgian Bay where it was observed at the 3 stations sampled. It was also detected in Nottawasaga Bay (0.07 ng/L), and in the Straits of Mackinac and the Detour Passage (stations # 64, 65, 66 and 67) where it ranged from 0.07 to 0.10 ng/L.

Mean heptachlor-epoxide concentrations in Lake Huron were higher than in Georgian Bay in 1986 and 1987, while in 1988, they were equivalent (Fig. 5). At the interface with Lake Michigan and in Saginaw Bay, the mean concentrations were 0.18 ng/L and 0.14 ng/L in 1988, respectively.

Gamma-chlordane was detected in 1986 in the North Channel at both ends of Cockburn Island (stations # 76 and 77). Alpha-chlordane was observed in 1986 in Owen Sound and in the offshore waters of Georgian Bay (stations # 1 and 29).

Table 3. Lake Huron 1986, 1987 and 1988 organic contaminants studies.

Parameter	Detection Limits	Values >P.D.L.	No. Samples	Mean Conc. (ng/l)	Standard Deviation	C.I. Conc. Minimum (ng/l)	(ng/l) Maximum
1986							
Alpha-BHC	.300	12	14	8.782	4.166	3.605	17.08
Lindane	.140	12	14	.7699	.1712	.5215	1.082
Heptachlor-Epoxide	.200E-01	12	14	.1874	.5463E-01	.1114	.2897
Dieldrin	.500E-01	12	14	.3865	.1020	.2421	.5754
Total PCBs	.810	3	14	.6089	.1403	.4064	.8652
Total DCBs	.300	14	14	.4739	.1925E-01	.4434	.5066
1987							
Alpha-BHC	.300	15	15	4.845	.3507	4.303	5.456
Lindane	.140	15	15	.5357	.3373E-01	.4831	.5940
Heptachlor-Epoxide	.200E-01	15	15	.1268	.5413E-02	.1182	.1360
Dieldrin	.500E-01	15	15	.3543	.2433E-01	.3165	.3965
Total DCBs	.300	13	15	.4349	.4272E-01	.3684	.5085
Fluoranthene	.350	15	15	1.019	.1512	.7985	1.299
1988							
Alpha-BHC	.300	5	5	2.743	.2844	2.314	3.251
Lindane	.140	5	5	.6049	.6041E-01	.5136	.7126
Heptachlor-Epoxide	.200E-01	5	5	.1437	.1744E-01	.1178	.1754
Dieldrin	.500E-01	5	5	.3219	.4259E-01	.2591	.3999
Total PCBs	.810	3	5	.9023	.1294	.7060	1.130
1,4-DCB	.510	3	5	.6025	.1017	.4503	.7834
Total DCBs	.300	4	5	.8164	.2641	.4558	1.317
Hexachlorobenzene	.400E-01	4	5	.7220E-01	.1729E-01	.4738E-01	.1039
2-Methylnaphthalene	.260	3	5	1.227	1.110	.1845	3.594
1-Methylnaphthalene	.280	4	5	1.460	.7076	.5862	2.874
Fluoranthene	.350	4	5	1.668	.9048	.5912	3.504

Table 4. Georgian Bay 1986, 1987 and 1988 organic contaminants studies.

Parameter	Detection Limits	Values >P.D.L.	No. Samples	Mean Conc. (ng/l)	Standard Deviation	C.I. Conc. Minimum (ng/l)	(ng/l) Maximum
1986							
Alpha-BHC	.300	7	7	5.013	.7387	3.937	6.384
Lindane	.140	7	7	.6447	.5633E-01	.5586	.7440
Heptachlor-Epoxide	.200E-01	7	7	.1663	.2350E-01	.1319	.2097
Dieldrin	.500E-01	7	7	.3170	.3555E-01	.2638	.3810
Total DCBs	.300	6	7	.5291	.6974E-01	.4225	.6511
124-TCB	.240	3	7	.2403	.3609E-01	.1857	.3039
1987							
Alpha-BHC	.300	8	8	2.971	.1409	2.748	3.211
Lindane	.140	8	8	.3326	.1344E-01	.3112	.3554
Heptachlor-Epoxide	.200E-01	8	8	.1028	.5750E-02	.9377E-01	.1127
Dieldrin	.500E-01	8	8	.2075	.1315E-01	.1870	.2302
Total DCBs	.300	7	8	.5647	.6907E-01	.4586	.6850
Fluoranthene	.350	8	8	.7706	.4862E-01	.6949	.8546
1988							
Alpha-BHC	.300	3	3	3.146	.2794	2.719	3.639
Lindane	.140	3	3	.4870	.2229E-01	.4518	.5250
Heptachlor-Epoxide	.200E-01	3	3	.1397	.5669E-02	.1307	.1493
Dieldrin	.500E-01	3	3	.2940	.3656E-02	.2881	.3001
Endrin	.300E-01	3	3	.5533E-01	.3057E-02	.5054E-01	.6058E-01
Total PCBs	.810	3	3	1.259	.8964E-01	1.120	1.415
1,4-DCB	.510	3	3	.7640	.3152E-01	.7140	.8175
1,2-DCB	.580	3	3	1.640	.5878E-01	1.546	1.739
Total DCBs	.300	3	3	2.433	.6706E-01	2.326	2.546
Hexachlorobenzene	.400E-01	3	3	.4533E-01	.2645E-02	.4119E-01	.4988E-01

Table 5. Lake Michigan's and Saginaw Bay's interface with Lake Huron 1988 organic contaminants study.

INTERFACE LAKE MICHIGAN/LAKE HURON

Parameter	Detection Limits	Values >P.D.L.	No. Samples	Mean Conc. (ng/l)	Standard Deviation	C.I. Conc. Minimum (ng/l)	Maximum
Alpha-BHC	.300	4	5	2.116	1.412	.5664	5.060
Lindane	.140	4	5	.3496	.1081	.2007	.5534
Heptachlor-Epoxide	.200E-01	4	5	.1832	.1170	.5244E-01	.4259
Dieldrin	.500E-01	4	5	.4176	.2497	.1310	.9312
Total PCBs	.300	4	5	.5131	.1307	.3270	.7543
Hexachlorobenzene	.400E-01	4	5	.5321E-01	.5419E-02	.4479E-01	.6255E-01
1-Methylnaphthalene	.280	4	5	1.068	.3864	.5523	1.810
Fluoranthene	.350	4	5	1.253	.5153	.5866	2.260

SAGINAW BAY AND/OR INTERFACE WITH LAKE HURON

Parameter	Detection Limits	Values >P.D.L.	No. Samples	Mean Conc. (ng/l)	Standard Deviation	C.I. Conc. Minimum (ng/l)	Maximum
Alpha-BHC	.300	7	8	2.523	.8301	1.393	4.099
Lindane	.140	7	8	.4549	.1090	.2984	.6548
Heptachlor-Epoxide	.200E-01	7	8	.1135	.3047E-01	.7054E-01	.1701
Dieldrin	.500E-01	7	8	.2377	.5881E-01	.1537	.3459
Total PCBs	.810	3	8	.9890	.4771	.3991	1.942
1,4-DCB	.510	3	8	.4860	.6238E-01	.3905	.5949
Total DCBs	.300	7	8	.7733	.1422	.5624	1.028
Pentachlorobenzene	.400E-01	3	8	.3921E-01	.1354E-02	.3703E-01	.4147E-01
Hexachlorobenzene	.400E-01	7	8	.6257E-01	.6732E-02	.5215E-01	.7421E-01
2-Methylnaphthalene	.260	3	8	.54232	Unbiased Estimate		
1-Methylnaphthalene	.280	8	8	1.638	.1377	1.427	1.880
Fluoranthene	.350	5	8	1.022	.4809	.4232	1.980

3.3.2 Total polychlorinated biphenyls

In 1986, total PCBs were detected near Lakeport and in the Straits of Mackinac (stations # 1, 63 and 64), in the offshore waters of Georgian Bay and in Nottawasaga Bay (stations # 4 and 29). PCBs were also observed in Saginaw Bay (station # 101).

In 1987, total PCBs were measured in Lake Huron near Pointe aux Barques (station # 17) and in Saginaw Bay (# 101).

Mean concentrations were estimated as follows in 1988: Lake Huron (0.90 ng/L), Georgian Bay (1.26 ng/L), and Saginaw Bay (0.99 ng/L).

3.3.3 Chlorobenzenes

Dichlorobenzenes were detected at most locations monitored from 1986 to 1988. Georgian Bay's mean lakewide concentrations for total dichlorobenzenes were higher than Lake Huron's throughout the study period (Fig. 6). These concentrations were stable in 1986 and 1987, but have increased significantly in 1988. The 1988 mean concentrations computed for the stations located at the interface with Lake Michigan were 0.51 ng/L, and 0.77 ng/L for those in Saginaw Bay. The highest mean concentrations for total dichlorobenzenes were recorded in 1988 in Georgian Bay (2.43 ng/L).

1,2,4-trichlorobenzene was detected only in 1986 near Lakeport, in Nottawasaga Bay, in Georgian Bay and in the North Channel (stations # 1, 4, 29, 84).

In 1986, 1,2,3,4-tetrachlorobenzene was observed in Lake Huron near Pointe aux Barques and in Saginaw Bay (stations # 17, 100). It was also measured in 1988 at station # 100 in Saginaw Bay.

In 1986, pentachlorobenzene was measured in Saginaw Bay at station # 101. While not detected in 1987, it reappeared in 1988 in Saginaw Bay and its interface with Lake Huron (stations # 94, 96 and 100), and in the open waters of Lake Huron (station # 12).

In 1986, hexachlorobenzene was detected in Lake Huron near Lakeport, in Saginaw Bay and Nottawasaga Bay (stations # 1, 4 and 100). While not detected in 1987, it was observed at most of the stations (18/21) monitored in the 1988 survey. The mean concentrations were then estimated as follows: Lake Huron (0.07 ng/L), Georgian Bay (0.04 ng/L), interface with Lake Michigan (0.05 ng/L), Saginaw Bay (0.06 ng/L) and Nottawasaga Bay (0.06 ng/L).

3.3.4 Polynuclear aromatic hydrocarbons

Fluoranthene was the only PAH measured in 1987. Other PAHs were monitored from 1988.

In 1987 and 1988, fluoranthene was ubiquitous, detected at 38 of the 45 of the stations monitored. In Lake Huron, mean levels of fluoranthene increased from 1987 (1.02 ng/L) to 1988 (1.67 ng/L) (Fig. 7). The highest concentrations were measured in 1988 in Nottawasaga Bay at stations # 4 (4.17 ng/L) and # 44 (5.27 ng/L). In 1988, at the interface with Lake Michigan, the mean concentration was 1.25 ng/L, and it was 1.02 ng/L in the Saginaw Bay.

1-Methylnaphthalene was detected at most of the stations in 1988, but was not observed in Georgian Bay. The average concentrations were as follows: Lake Huron (1.46 ng/L), interface with Lake Michigan (1.25 ng/L) and Saginaw Bay (1.64 ng/L).

In 1988, 2-methylnaphthalene was measured at station # 4 in Nottawasaga Bay (1.07 ng/L). Detected at 3 of the 5 stations in Lake Huron, the mean concentration was estimated at 1.23 ng/L. In Saginaw Bay the unbiased estimate of the mean was 0.54 ng/L.

In 1988, indene (2.99 ng/L), acenaphthylene (2.67 ng/L), and acenaphthene (1.13 ng/L) were detected in the Detour Passage (station # 67). Pyrene (1.12 ng/L) was measured in the Straits of Mackinac (station # 64). Phenanthrene was also observed at stations # 64 (1.60 ng/L) and # 67 (4.48 ng/L).

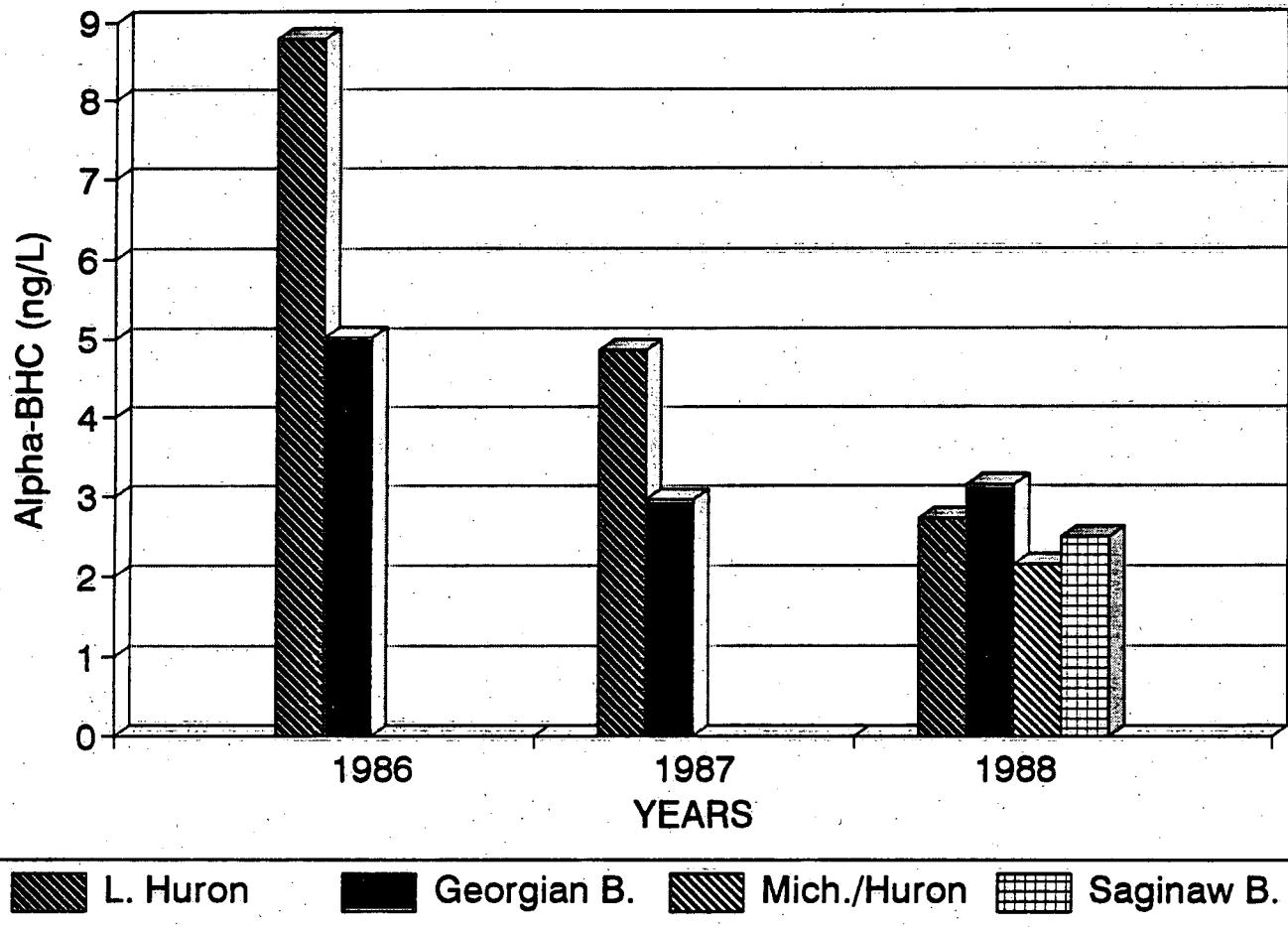


Fig. 2 Mean alpha-BHC lakewide concentrations for Lake Huron and
Georgian Bay 1986-1988.

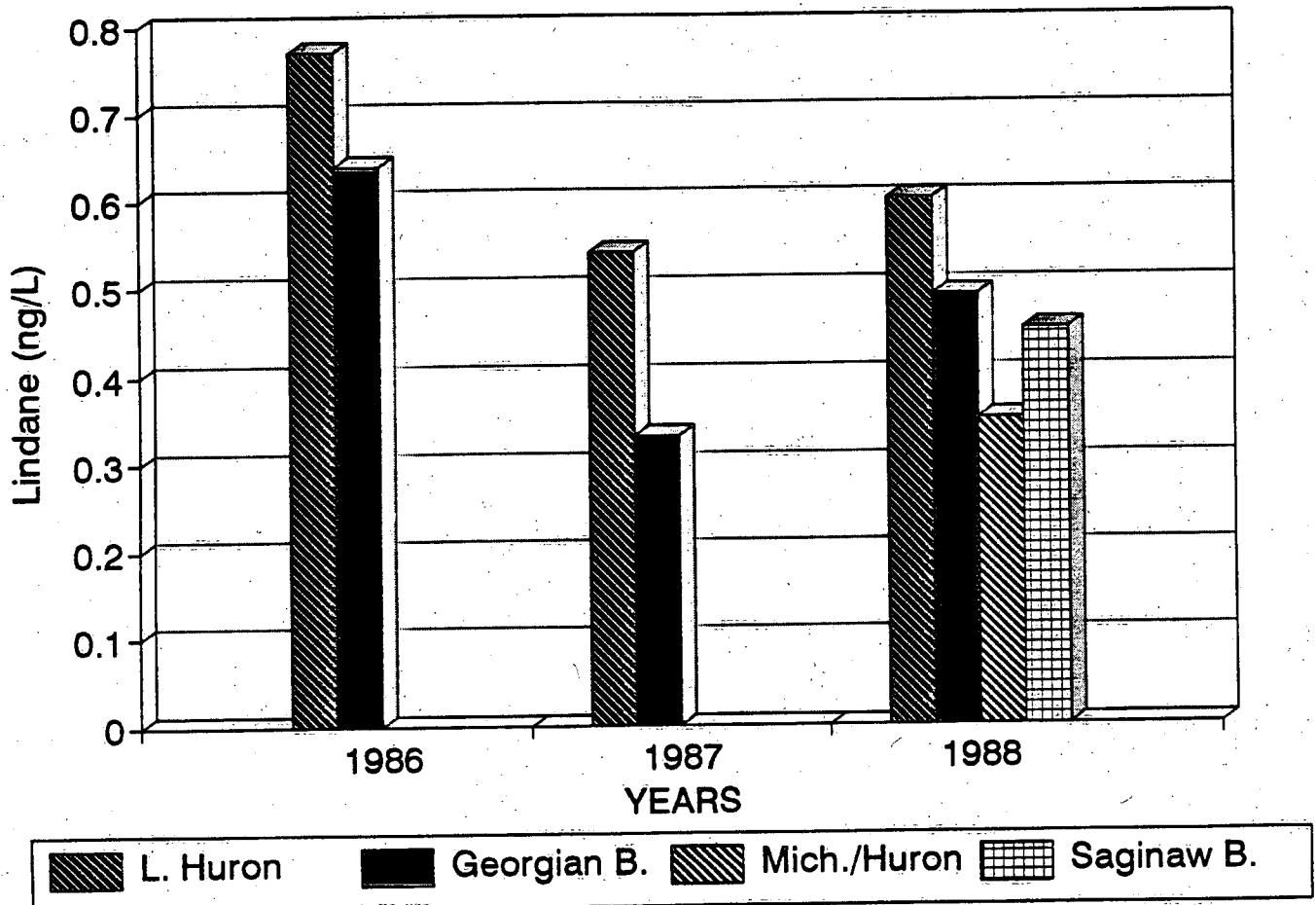


Fig. 3 Mean lindane lakewide concentrations for Lake Huron and
Georgian Bay 1986-1988.

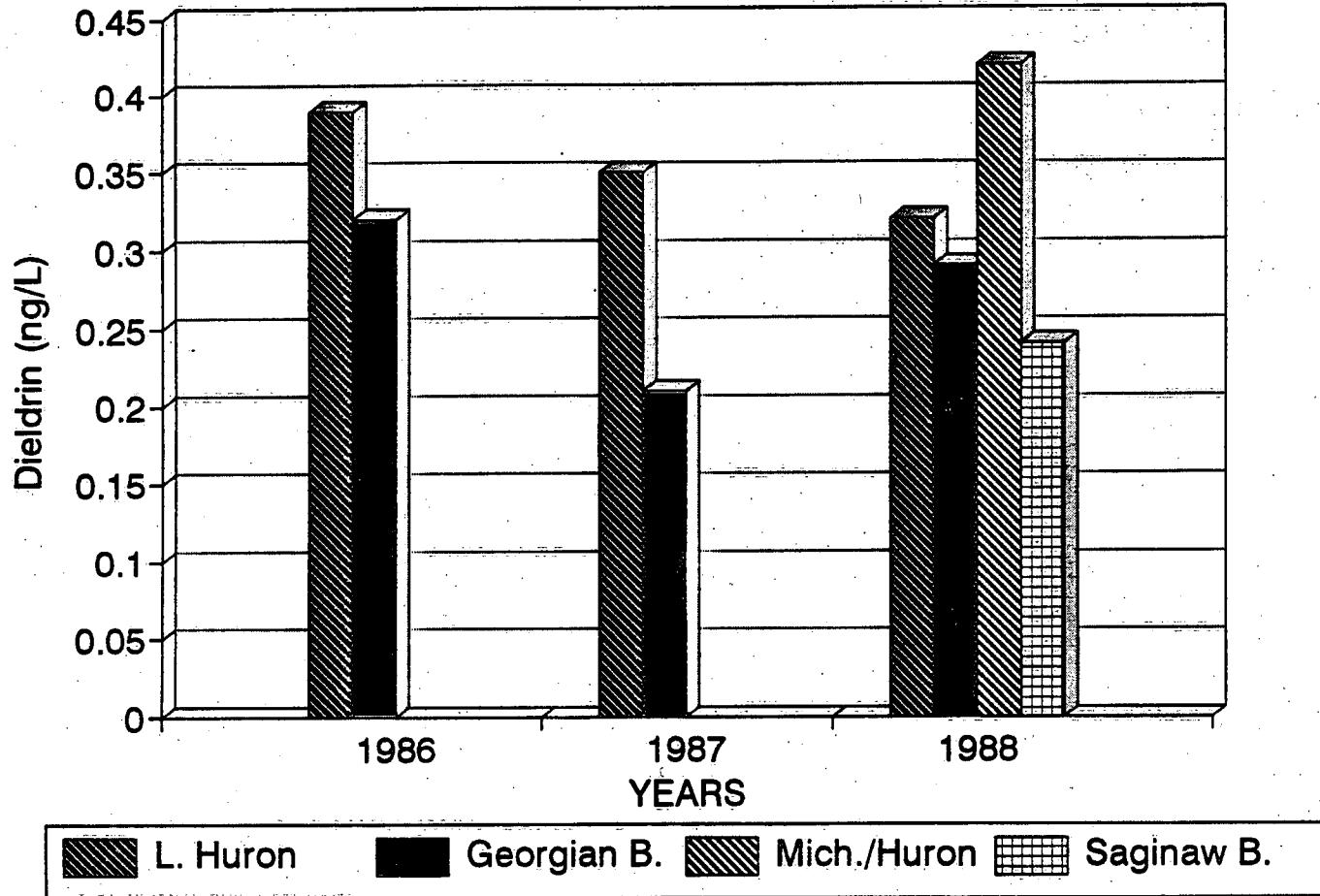


Fig. 4 Mean dieldrin lakewide concentrations for Lake Huron and
Georgian Bay 1986-1988.

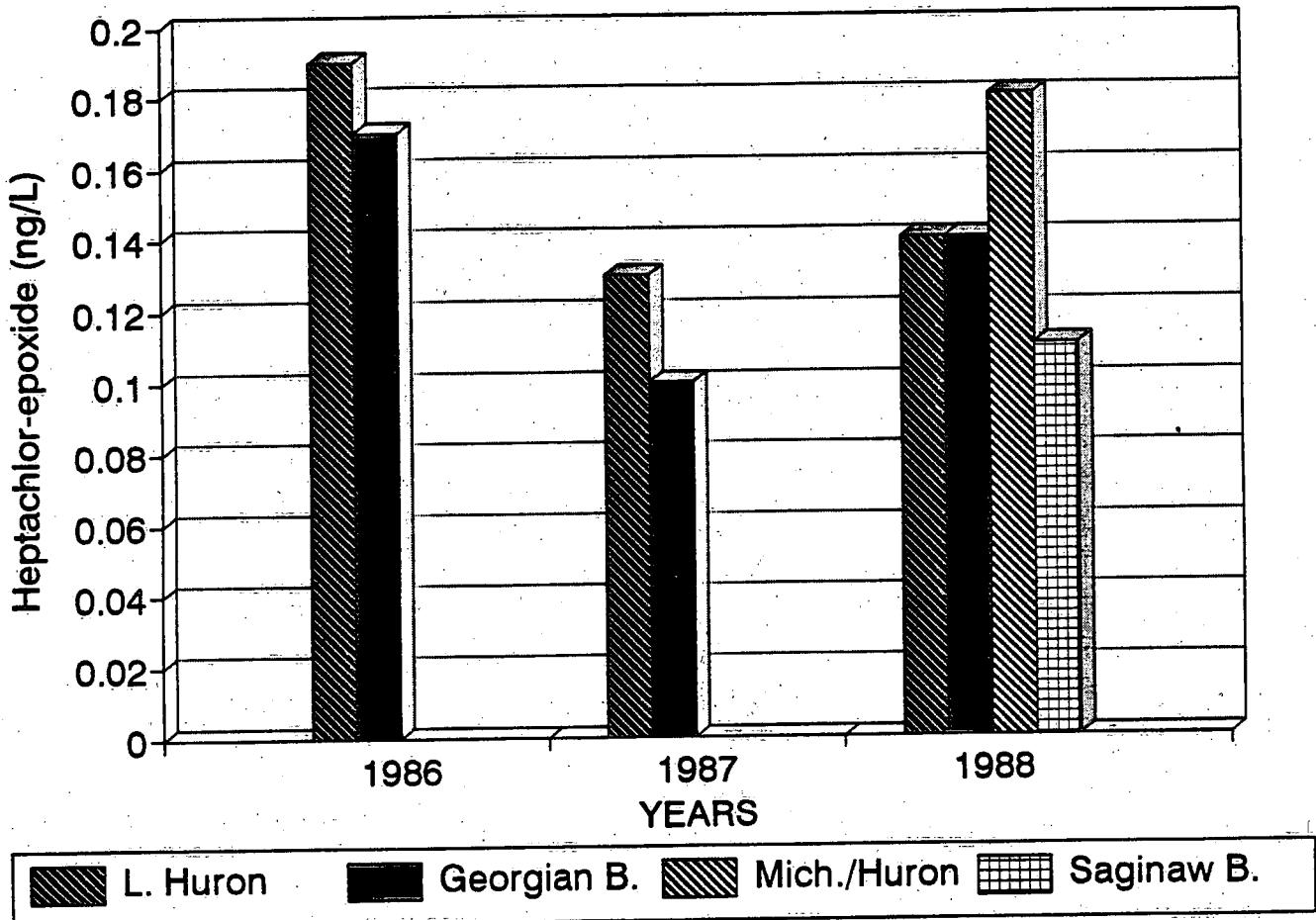


Fig. 5 Mean heptachlor-epoxide lakewide concentrations for Lake Huron and Georgian Bay 1986-1988.

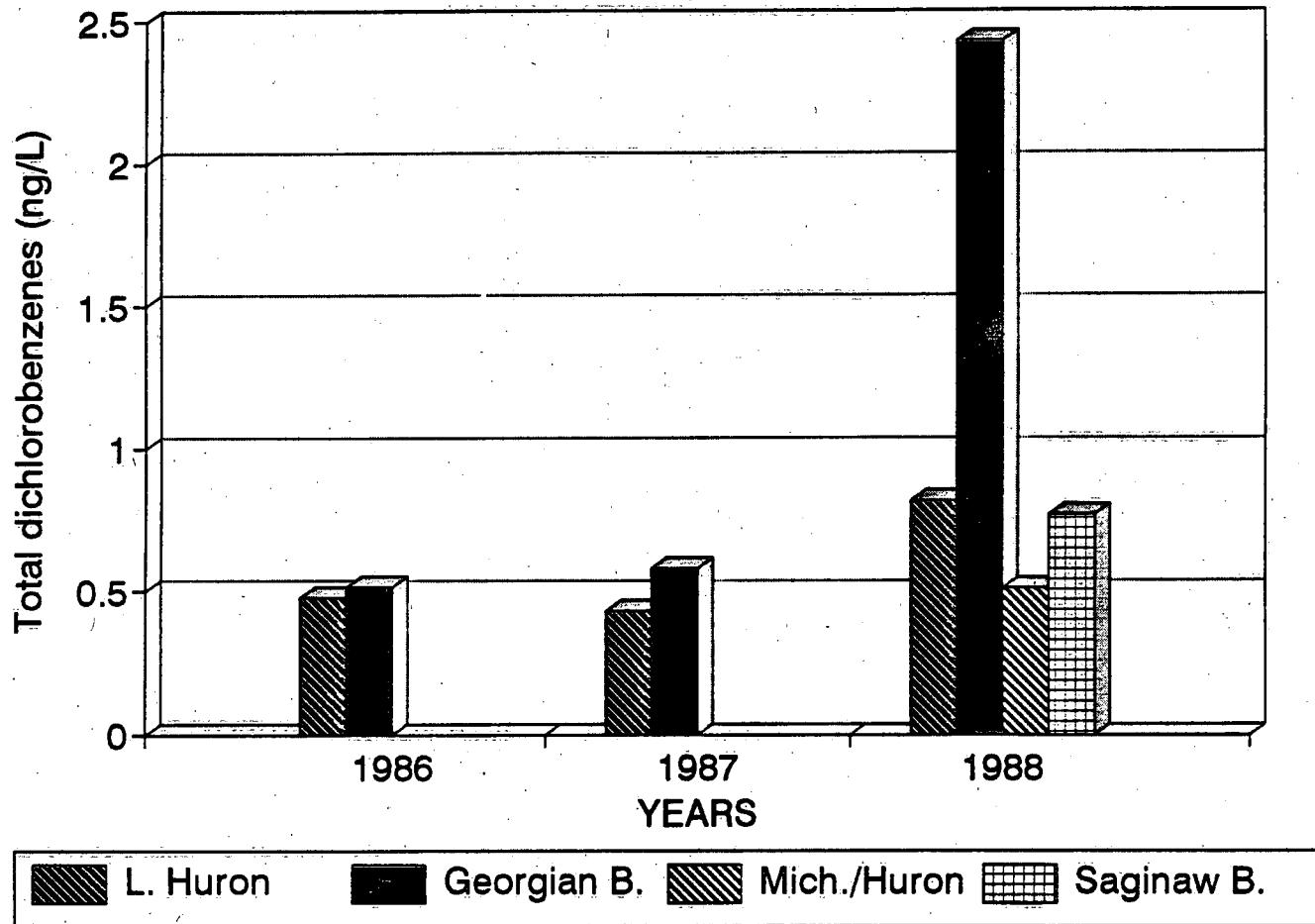


Fig. 6 Mean total dichlorobenzene lakewide concentrations for Lake Huron and Georgian Bay 1986-1988.

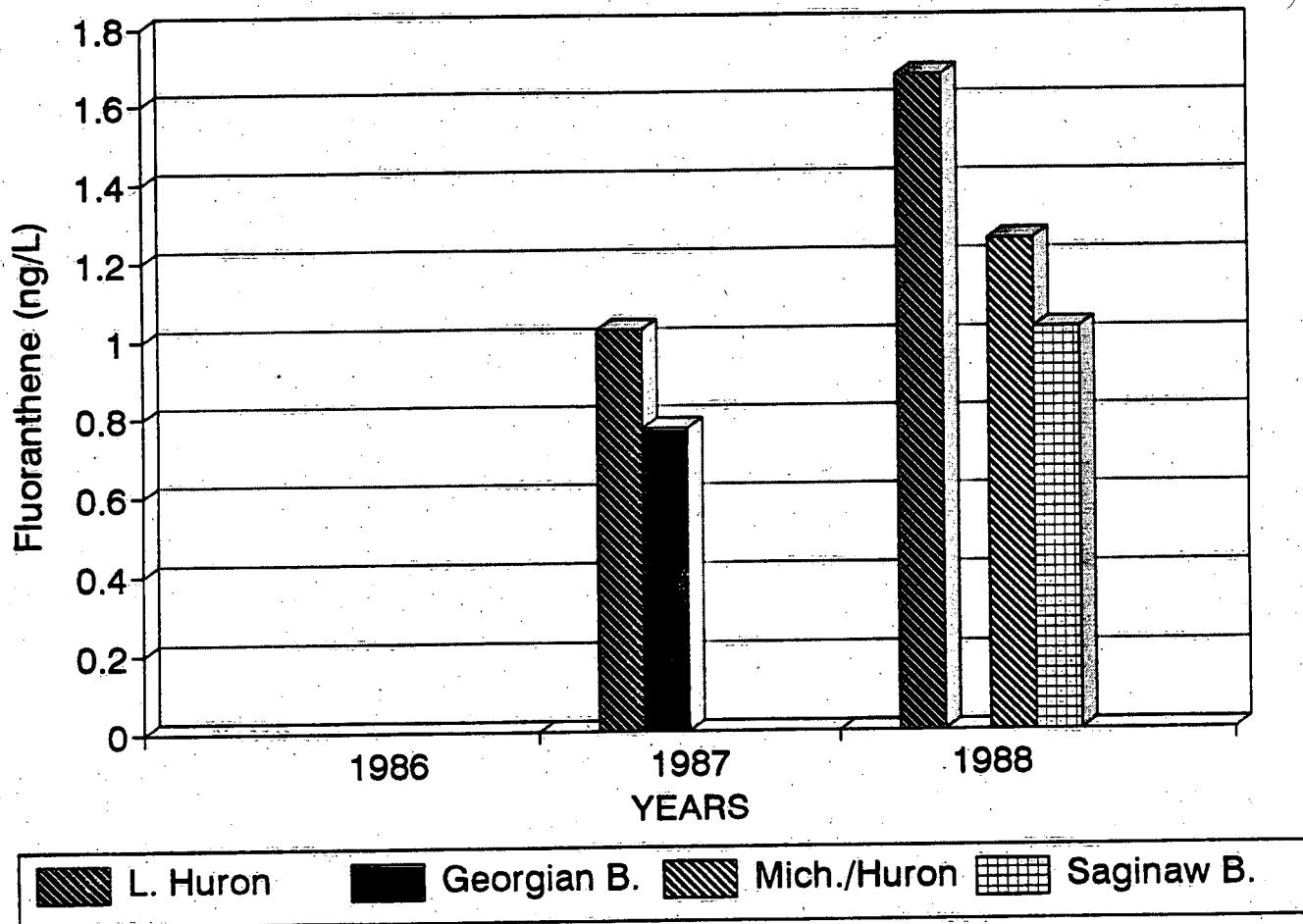


Fig. 7 Mean fluoranthene lakewide concentrations for Lake Huron and Georgian Bay 1986-1988.

3.4 Lake Erie

Lake Erie's 1986 mean lakewide concentrations are summarized in Table 6.

3.4.1 Organochlorine pesticides

Alpha-BHC, lindane, heptachlor-epoxide, and dieldrin were detected at 18 of the 19 stations monitored in the 1986 Lake Erie survey. The mean concentrations of the BHC isomers were: alpha (3.95 ng/L) and gamma (1.08 ng/L). Lakewide concentrations averaged 0.38 ng/L for dieldrin, and 0.16 ng/L for heptachlor-epoxide.

The chlordane isomers (alpha and gamma) were detected at almost half of the stations, as they averaged 0.06 and 0.03 ng/L, respectively.

p,p'-DDE was detected at the mouth of the Detroit (0.10 ng/L) and Maumee Rivers (0.07 ng/L) (stations # 213 and 215).

3.4.2 Polychlorinated biphenyls

PCBs, detected at 13 of the 19 stations, averaged 1.22 ng/L.

3.4.3 Chlorobenzenes

Dichlorobenzenes were ubiquitous and total DCBs averaged 1.69 ng/L. Concentrations of 1,2 and 1,4-dichlorobenzene at the mouth of the Detroit River ranged from 1 to 5 ng/L, identifying it as a source to Lake Erie. 1,2,4-trichlorobenzene was detected at 14 of the 19 stations sampled and averaged 0.35 ng/L. Mean lakewide concentrations of 1,3,5-trichlorobenzene were estimated at 0.02 ng/L while detected at 5 of 19 stations. 1,2,3,4-tetrachlorobenzene (0.09 ng/L) was measured near Ashtabula (station # 223). Pentachlorobenzene (0.05 ng/L) was detected at the mouth of the Detroit River (station # 212). Hexachlorobenzene, detected at half of the locations (9/19), averaged 0.05 ng/L.

Table 6. Lake Erie 1986 organic contaminants study.

Parameter	Detection Limits	Values >P.D.L.	No. Samples	Mean Conc. (ng/l)	Standard Deviation	C.I. Conc. Minimum	(ng/l) Maximum
Alpha-BHC	.300	18	19	3.946	.6307	2.998	5.064
Lindane	.140	18	19	1.078	.1614	.8340	1.363
Heptachlor-Epoxide	.200E-01	18	19	.1643	.2236E-01	.1302	.2035
Gamma-Chlordane	.300E-01	8	19	.3325E-01	.5616E-02	.2485E-01	.4324E-01
Alpha-Chlordane	.600E-01	7	19	.5732E-01	.6570E-02	.4719E-01	.6872E-01
Dieldrin	.500E-01	18	19	.3835	.6449E-01	.2870	.4982
Total PCBs	.810	13	19	1.222	.1875	.9390	1.553
1,3-DCB	.300	6	19	.2668	.3741E-01	.2099	.3325
1,4-DCB	.510	13	19	1.232	.3451	.7482	1.875
Total DCBs	.300	19	19	1.686	.3228	1.232	2.308
135-TCB	.200E-01	5	19	.2308E-01	.1252E-01	.8184E-02	.4849E-01
124-TCB	.240	14	19	.3536	.3352E-01	.3014	.4112
Hexachlorobenzene	.400E-01	9	19	.4719E-01	.8826E-02	.3412E-01	.6302E-01

3.5 Lake Ontario

The Lake Ontario 1986, 1988 and 1990 mean lakewide concentrations for organic contaminants are given in Table 7.

3.5.1 Organochlorine pesticides

Alpha-BHC, lindane and dieldrin were widespread from 1986 to 1990. p,p'-DDE, alpha-chlordane and endrin were detected in 1986 and 1988, but were not observed in 1990.

The alpha-BHC concentrations measured in 1986 and 1988 at the mouth of the Niagara and Oswego Rivers, and in Toronto Harbour were comparable to the lakewide means (Fig. 8). In 1990, the lakewide averages were lower than those computed for the Niagara River and Toronto Harbour. The Niagara River and the Toronto Harbour appear to be sources of lindane to Lake Ontario (Fig. 9). The mean lakewide concentrations for both BHC isomers decreased from 1986 to 1990, Black River Bay showing the lowest overall levels.

Heptachlor-epoxide was ubiquitous in 1986 and 1988, but its detection rate dropped by half in 1990. The maximum concentration of heptachlor-epoxide was measured in 1988 at station # 8 (Toronto Harbour) (Fig. 10).

Methoxychlor was observed in 1988 (0.24 ng/L) at the Niagara River mouth (station # 22).

p,p'-DDT was detected exclusively in 1988 at station # 21 (Niagara River mouth) (0.14 ng/L) and station # 4 in Toronto Harbour (0.23 ng/L). In 1986, p,p'-DDE was detected at several locations: stations # 17 (near Port Dalhousie), # 93 (near Wilson, N.Y.), # 86 (Port Weller Harbour) and # 71 (Oswego River mouth). In 1988, p,p'-DDE was measured at stations # 22 (Niagara River mouth), # 103 (near Kingston) # 86 (Port Weller Harbour), # 71 (Oswego River mouth) and # 76 (Black River Bay). None of the DDT and metabolites were observed in 1990.

In 1986, endrin was detected at a third of the stations (9/24) monitored, while in 1988, it was measured at half the stations (17/26). It was not detected in 1990.

Gamma-chlordane was detected in Toronto Harbour in 1988 and 1990. Alpha-chlordane was measured at that location in 1986 and 1988, but not in 1990. Toronto Harbour appears to be a source of chlordane to Lake Ontario.

Table 7. Lake Ontario 1986, 1988 and 1990 organic contaminants studies.

Parameter	Detection Limits	Values >P.D.L.	No. Samples	Mean Conc. (ng/l)	Standard Deviation	C.I. Conc. Minimum	(ng/l) Maximum
<u>1986</u>							
Alpha-BHC	.300	24	24	4.268	.1557	4.020	4.531
Lindane	.140	24	24	1.376	.8428E-01	1.245	1.522
Heptachlor-Epoxide	.200E-01	24	24	.1167	.5048E-02	.1087	.1253
Alpha-Chlordane	.600E-01	3	24	.4734E-01	.6930E-02	.3684E-01	.5954E-01
Dieldrin	.500E-01	24	24	.3430	.1758E-01	.3154	.3731
Endrin	.300E-01	9	24	.4870E-01	.1798E-01	.2482E-01	.8335E-01
Total PCBs	.810	15	24	1.137	.1325	.9332	1.367
1,3-DCB	.300	10	24	.3366	.6282E-01	.2436	.4493
1,4-DCB	.510	23	24	1.695	.1934	1.397	2.031
1,2-DCB	.580	9	24	.9693	.3850	.4669	1.718
Total DCBs	.300	23	24	3.026	.5112	2.261	3.936
135-TCB	.200E-01	14	24	.3087E-01	.4702E-02	.2377E-01	.3917E-01
124-TCB	.240	22	24	.5205	.7145E-01	.4117	.6458
123-TCB	.900E-01	6	24	.1028	.5166E-01	.3972E-01	.2066
1234-TeCB	.900E-01	5	24	.1440	.1422	.1752E-01	.4466
Pentachlorobenzene	.400E-01	4	24	.6145E-01	.6358E-01	.2619E-02	.2267
Hexachlorobenzene	.400E-01	19	24	.6032E-01	.4510E-02	.5321E-01	.6800E-01
<u>1988</u>							
Alpha-BHC	.300	23	26	3.822	.9050	2.520	5.479
Lindane	.140	23	26	.8720	.1337	.6702	1.108
Heptachlor-Epoxide	.200E-01	23	26	.2529	.5641E-01	.1711	.3556
Gamma-Chlordane	.300E-01	3	26	.1497E-01	.5553E-02	.7608E-02	.2568E-01
Alpha-Chlordane	.600E-01	6	26	.4746E-01	.1172E-01	.3070E-01	.6903E-01
P,P-DDE	.600E-01	3	26	.06000	Unbiased Estimate		
Dieldrin	.500E-01	23	26	.3617	.5974E-01	.2721	.4678
Endrin	.300E-01	17	26	.5633E-01	.8679E-02	.4323E-01	.7167E-01
Total PCBs	.810	11	26	.9060	.1300	.7087	1.135
1,3-DCB	.300	4	26	.1854	.7563E-01	.8740E-01	.3331
1,4-DCB	.510	17	26	.9631	.1575	.7267	1.243
1,2-DCB	.580	3	26	.7998	1.587	.4304E-02	2.892
Total DCBs	.300	21	26	1.681	.4914	.9968	2.601
135-TCB	.200E-01	14	26	.2456E-01	.3177E-02	.1970E-01	.3011E-01
124-TCB	.240	16	26	.3542	.6322E-01	.2601	.4671
123-TCB	.900E-01	5	26	.8020E-01	.4289E-01	.2892E-01	.1671
1234-TeCB	.900E-01	3	26	.3789	1.311	.3245E-05	.2767
Pentachlorobenzene	.400E-01	7	26	.3813E-01	.1306E-01	.2050E-01	.6306E-01
Hexachlorobenzene	.400E-01	22	26	.6538E-01	.4009E-02	.5901E-01	.7216E-01
1234-THNP	.250	5	26	.91767	Unbiased Estimate		
2-Methylnaphthalene	.260	13	26	2.326	1.814	.4774	6.166
1-Methylnaphthalene	.280	12	26	1.114	.6274	.3778	2.394
Acenaphthene	.300	5	26	.4457	.4403	.5413E-01	1.383
Fluorene	.190	9	26	1.964	2.724	.7720E-01	7.299
Phenanthrene	.130	14	26	25.70	45.79	.2830	97.64
Pyrene	.320	13	26	10.01	12.57	.5819	35.68
Fluoranthene	.350	15	26	11.61	11.87	1.285	36.82
<u>1990</u>							
Alpha-BHC	.300	32	37	1.534	.2290	1.187	1.938
Lindane	.140	34	37	.5487	.5079E-01	.4694	.6359
Heptachlor-Epoxide	.200E-01	18	37	.9982E-01	.4985E-01	.3885E-01	.1999
Dieldrin	.500E-01	36	37	.2858	.2235E-01	.2507	.3239
Total PCBs	.810	19	37	1.198	.1845	.9195	1.524
1,4-DCB	.510	33	37	1.195	.9167E-01	1.051	1.351
Total DCBs	.300	33	37	1.312	.1501	1.081	1.573
124-TCB	.240	4	37	.1368	.3678E-01	.8487E-01	.2050
123-TCB	.900E-01	3	37	.4452E-01	.1607E-01	.2307E-01	.7539E-01
1234-TeCB	.900E-01	5	37	.5729E-01	.1158E-01	.4029E-01	.7820E-01
Hexachlorobenzene	.400E-01	9	37	.3608E-01	.9445E-02	.2270E-01	.5356E-01
Indene	.200	23	37	.3216	.4619E-01	.2515	.4029
1234-THNP	.250	27	37	.3448	.2386E-01	.3071	.3853
2-Methylnaphthalene	.260	36	37	1.433	.2640	1.042	1.906
1-Methylnaphthalene	.280	33	37	1.066	.1937	.7783	1.412
Acenaphthylene	.190	11	37	.2075	.6290E-01	.1205	.3258
Acenaphthene	.300	5	37	.1583	.4636E-01	.9384E-01	.2452
Fluorene	.190	22	37	.4137	.8313E-01	.2916	.5637
Phenanthrene	.130	35	37	1.248	.1949	.9545	1.593
Pyrene	.320	19	37	.4479	.6613E-01	.3478	.5644
Fluoranthene	.350	30	37	.8722	.1192	.6907	1.081
Benz(k/B) Fluoranthene	.490	4	37	.28478	Unbiased Estimate		

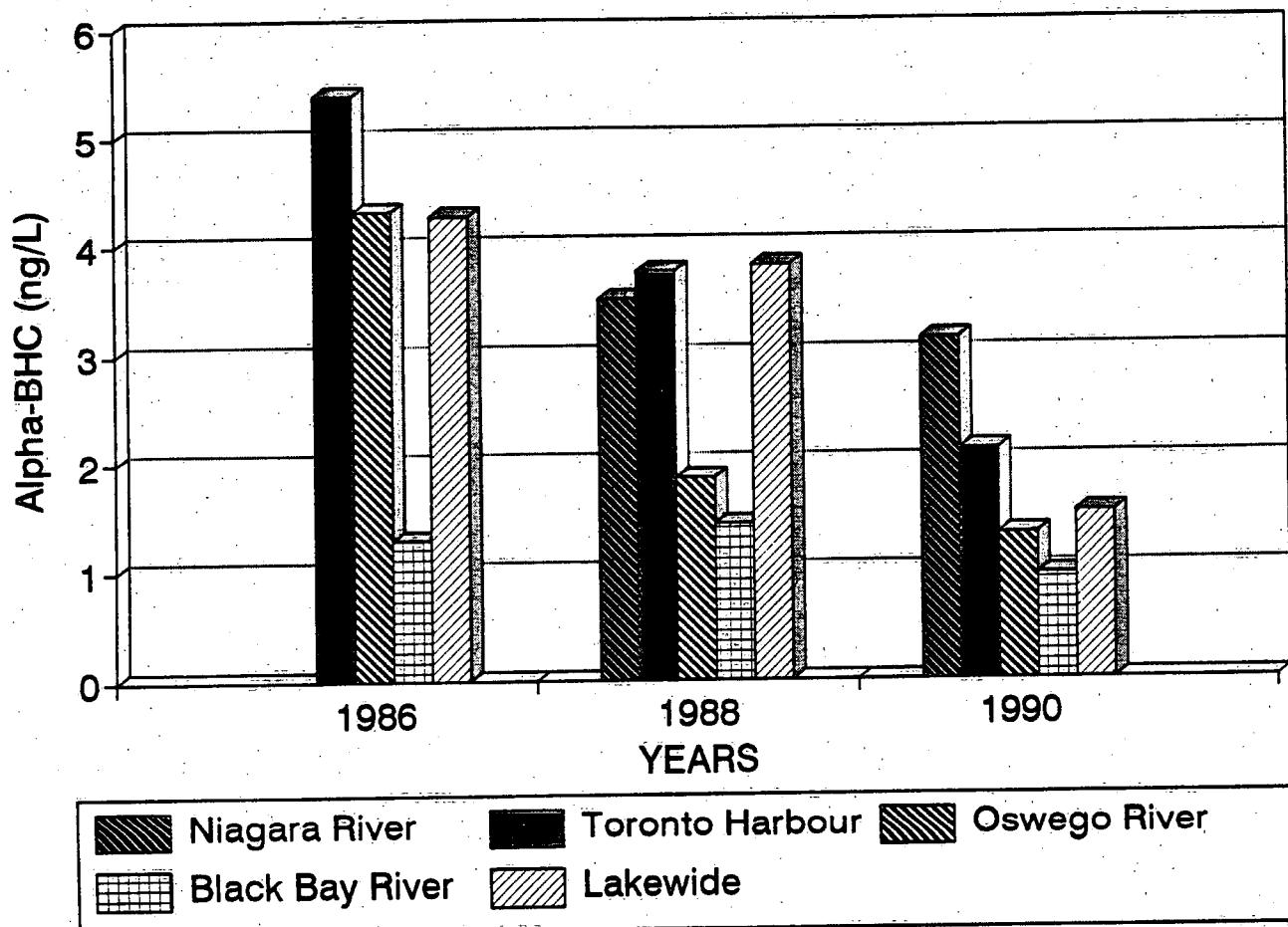
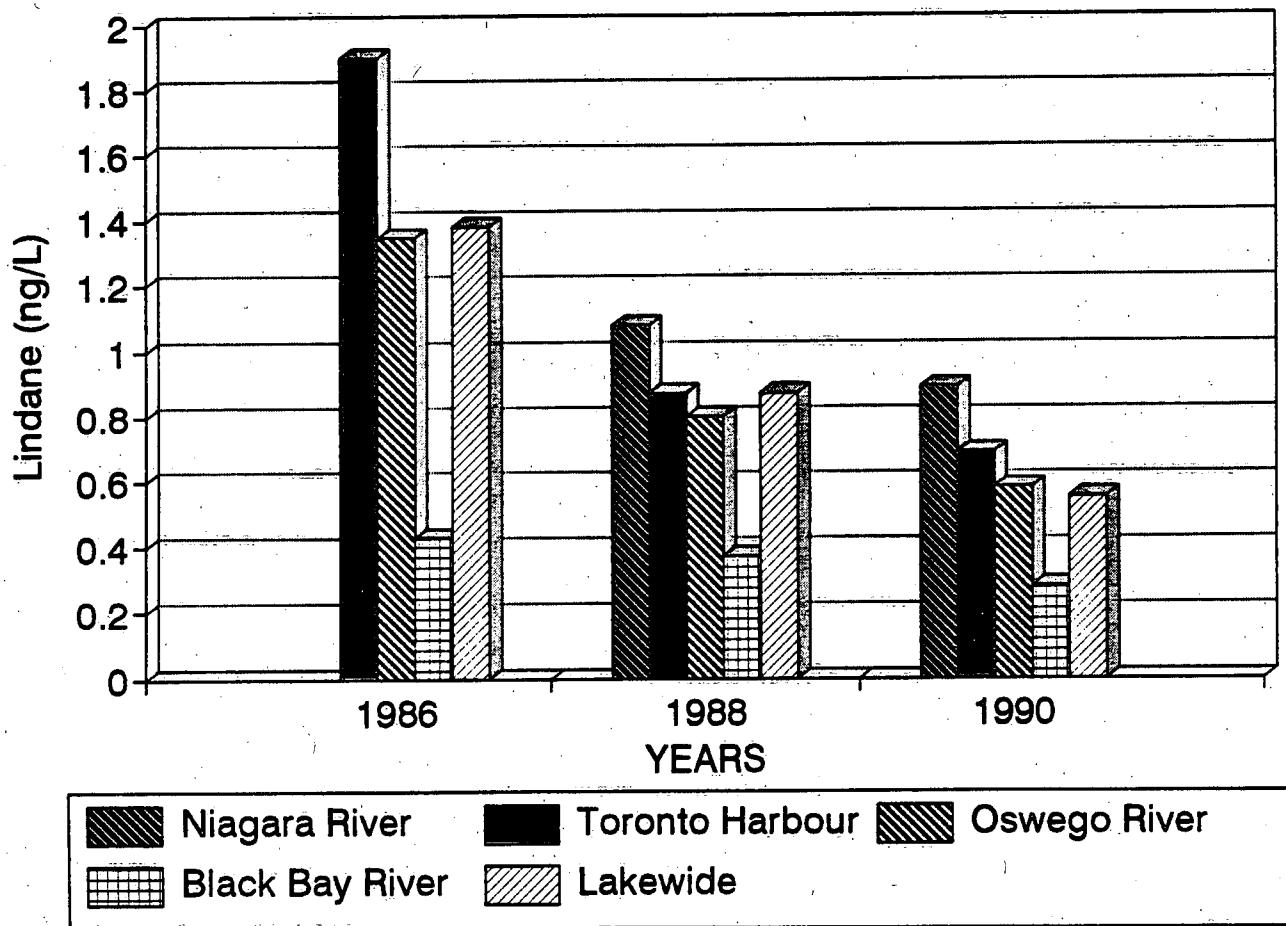


Fig. 8 Mean alpha-BHC lakewide concentrations for Lake Ontario
1986-1990.



**Fig. 9 Mean lindane lakewide concentrations for Lake Ontario
1986-1990.**

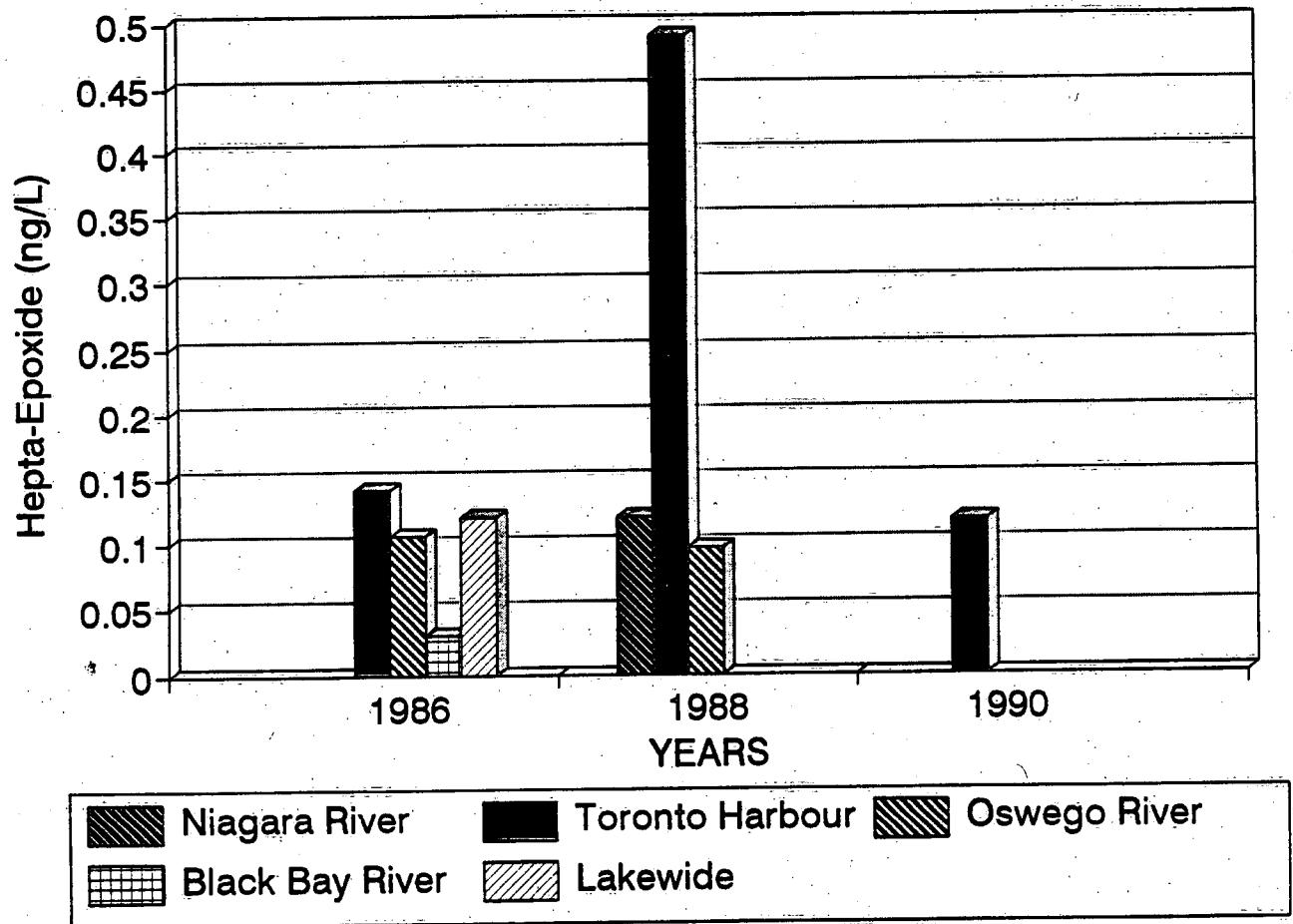


Fig. 10 Mean heptachlor-epoxide lakewide concentrations for Lake Ontario 1986-1990.

3.5.2 Total polychlorinated biphenyls

PCBs in Lake Ontario have been detected at about half the stations monitored from 1986 to 1990, and their lakewide levels ranged between 0.91 and 1.19 ng/L (Fig. 11). The Black River Bay, where the highest overall concentrations were reported, is a major source of PCBs to Lake Ontario. In 1986, the mean PCB concentrations (2.23 ng/L) measured at station # 86 (Port Weller Harbour) were higher than across the lake. Lack of valid data for subsequent years impedes the assessment of trends. Nonetheless, the Niagara River is a source of PCBs to Lake Ontario.

3.5.3 Chlorobenzenes

Dichlorobenzenes were widespread and their mean lakewide concentrations decreased from 1986 to 1990 (Fig. 12). At station # 71 (Oswego River mouth), total DCBs reached a maximum of 27.89 ng/L in 1988. 1,2,4- and 1,3,5-trichlorobenzenes were detected at about half the stations in 1986 and 1988, the latter being detected at only one location (station # 21) in 1990. Pentachlorobenzene was sparsely measured throughout the study period 1986-1990.

Hexachlorobenzene was detected at most of the locations monitored in 1986 and 1988, but in 1990, its detection rate fell to 25%. It was never observed at stations # 76 and # 97 (Black River Bay). Hexachlorobenzene was detected at stations # 8 (Toronto Harbour), # 86 (Port Weller Harbour) and # 71 (Oswego River mouth) in 1986 and 1988, but not in 1990 (Fig. 13).

Locations under the influence of the Niagara River plume (stations # 1, 3 17, 21, 22, 96) all showed high levels of chlorobenzenes, demonstrating its contribution to Lake Ontario.

3.5.4 Polynuclear aromatic hydrocarbons

The mean lakewide PAH concentrations generally decreased from 1988 to 1990. Maxima overall concentrations were recorded in 1990 at station # 3, near Grimsby.

The 1988 mean levels of fluoranthene, pyrene and phenanthrene were at least ten times higher than those measured in 1990 (Fig. 14 to 16), due partly to concentrations (23 to 34 ng/L) measured near Bouchette Point (station # 31). The detection rates of these compounds increased largely from 1988 to 1990. In 1988, high levels of fluoranthene were measured at station # 71 (Oswego River mouth). The Oswego River and the Black River Bay showed high concentrations of fluoranthene, phenanthrene, pyrene and 1- and 2-methylaphthalene and were sources to the lake in 1990. Indene was detected in 1988 at only 4 of the 28 stations sampled in Lake Ontario, but was found at most locations in 1990. Fluorene and 1,2,3,4-tetrahydronaphthalene were detected at 1/3 or less of the stations in 1988, and at 2/3 of them in 1990.

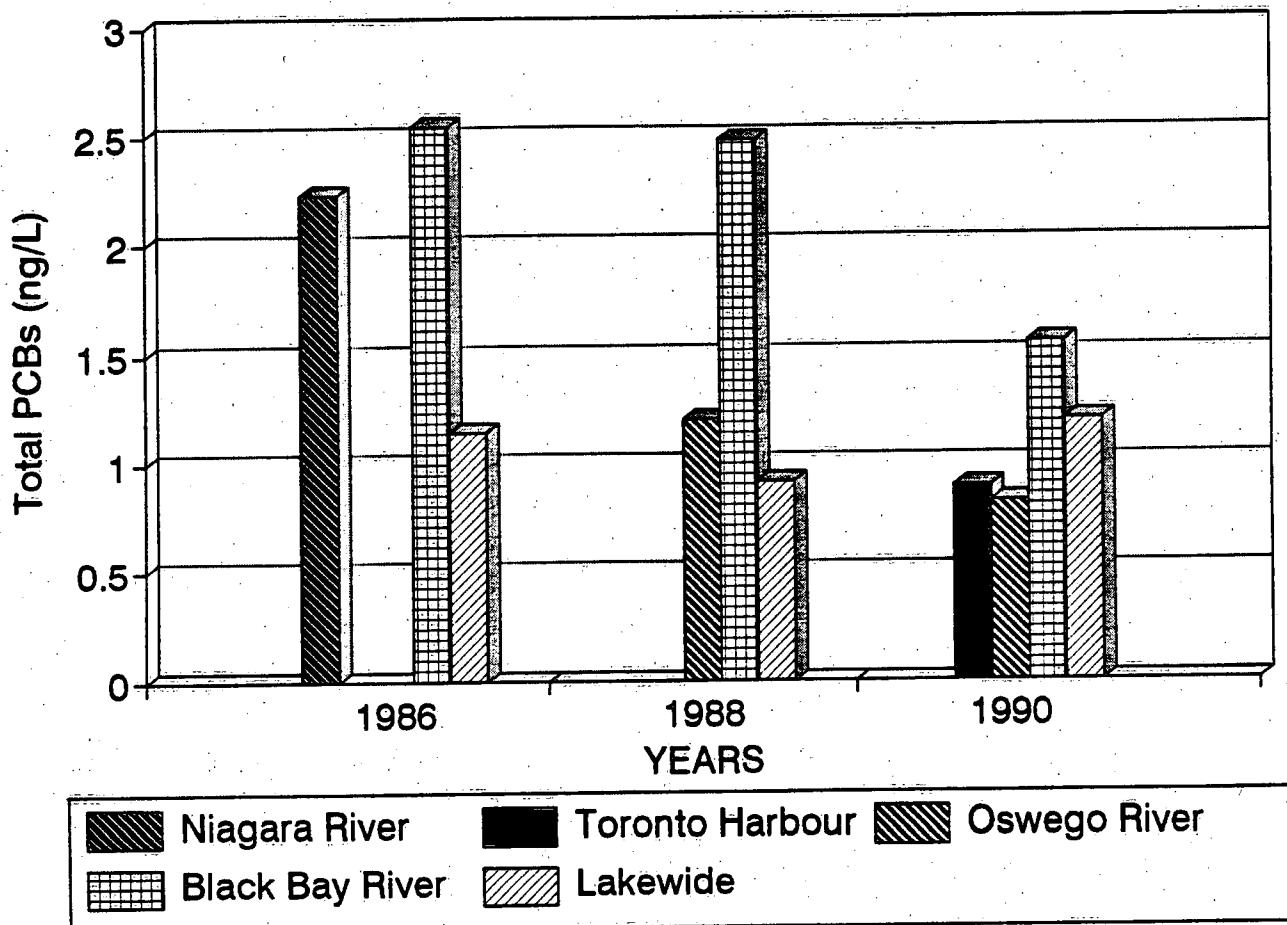


Fig. 11 Mean total PCB lakewide concentrations for Lake Ontario
1986-1990.

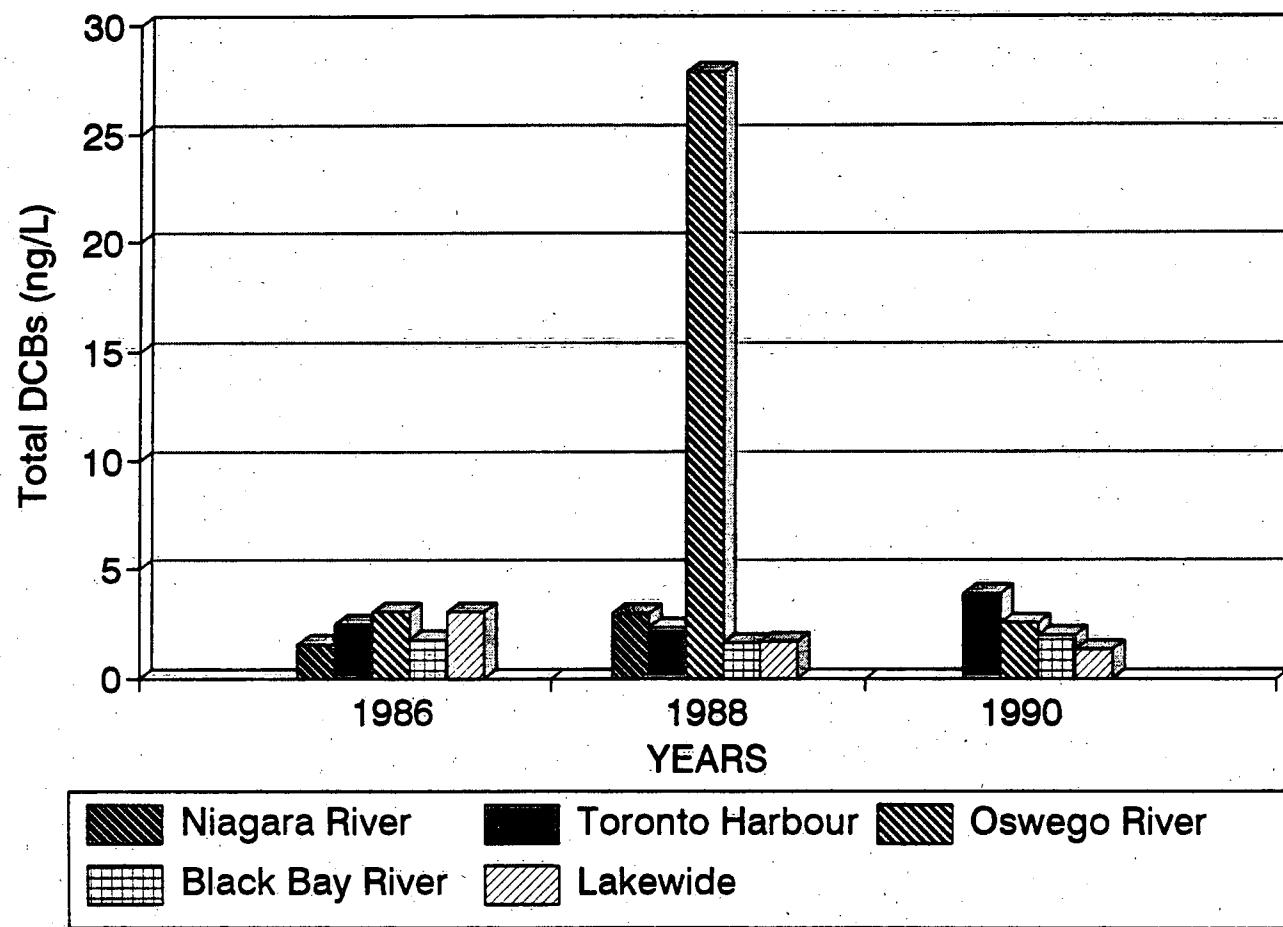


Fig. 12 Mean total dichlorobenzene lakewide concentrations
for Lake Ontario 1986-1990.

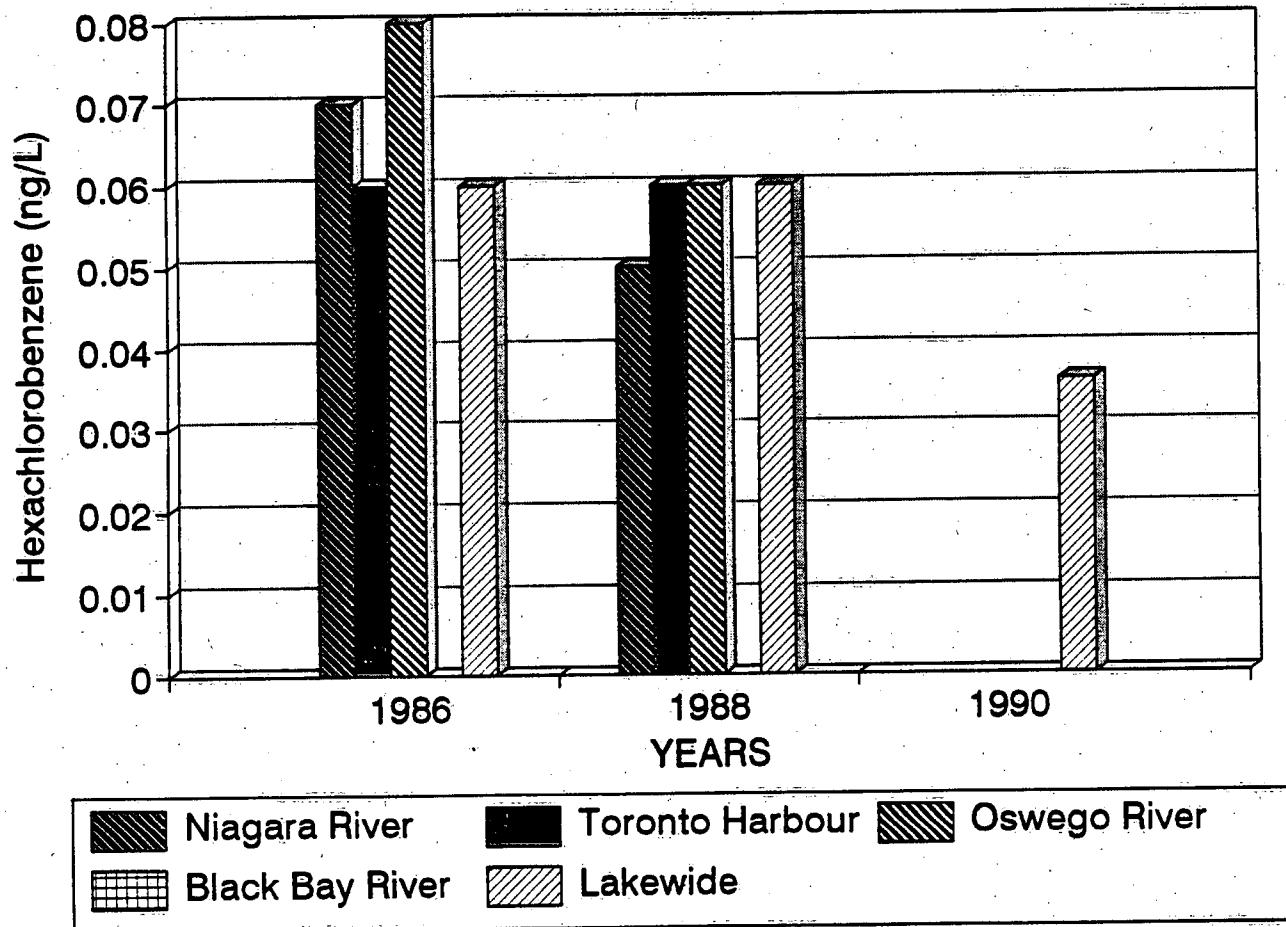


Fig. 13 Mean hexachlorobenzene lakewide concentrations for Lake Ontario 1986-1990.

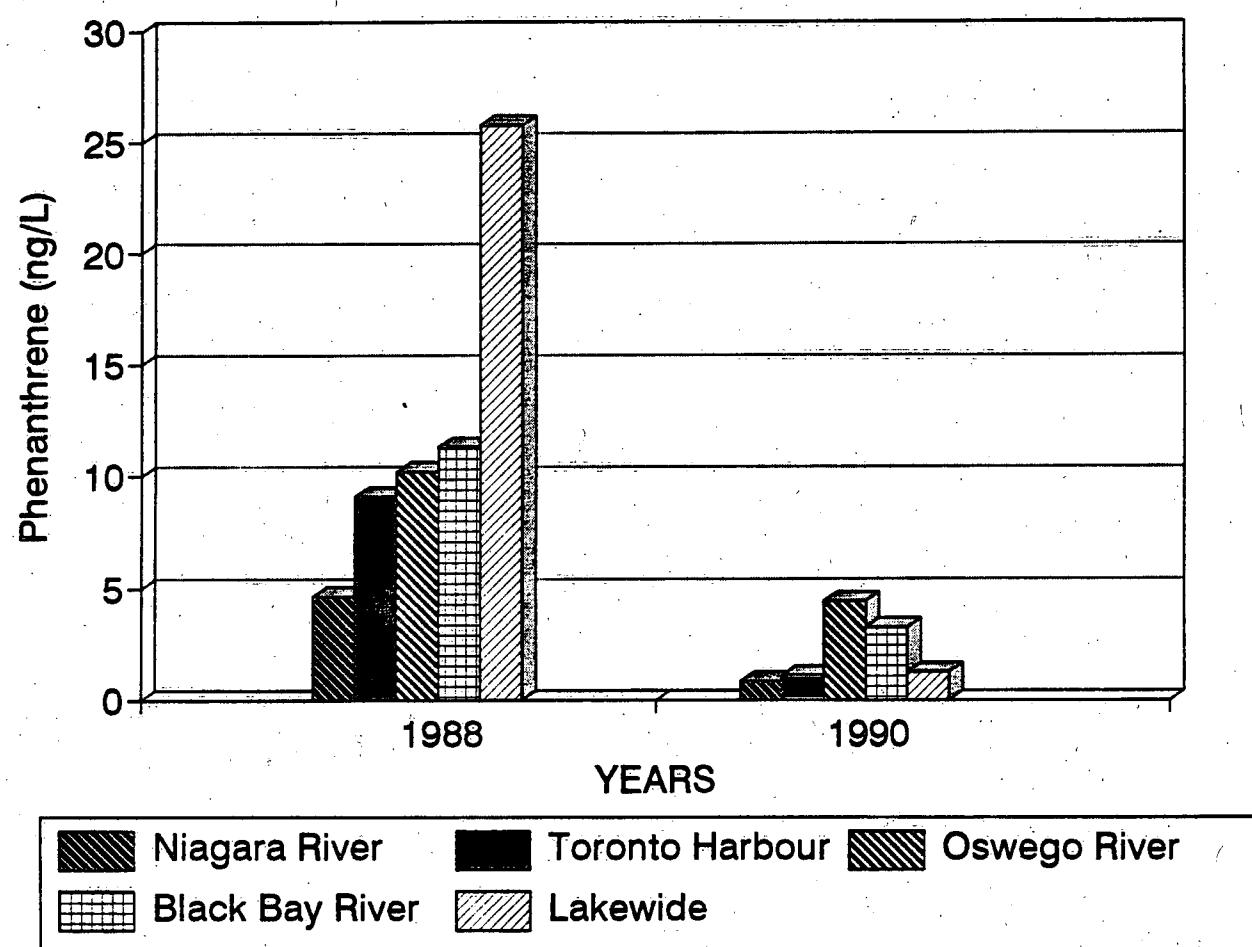


Fig. 14 Mean phenanthrene concentrations for Lake Ontario 1988-1990.

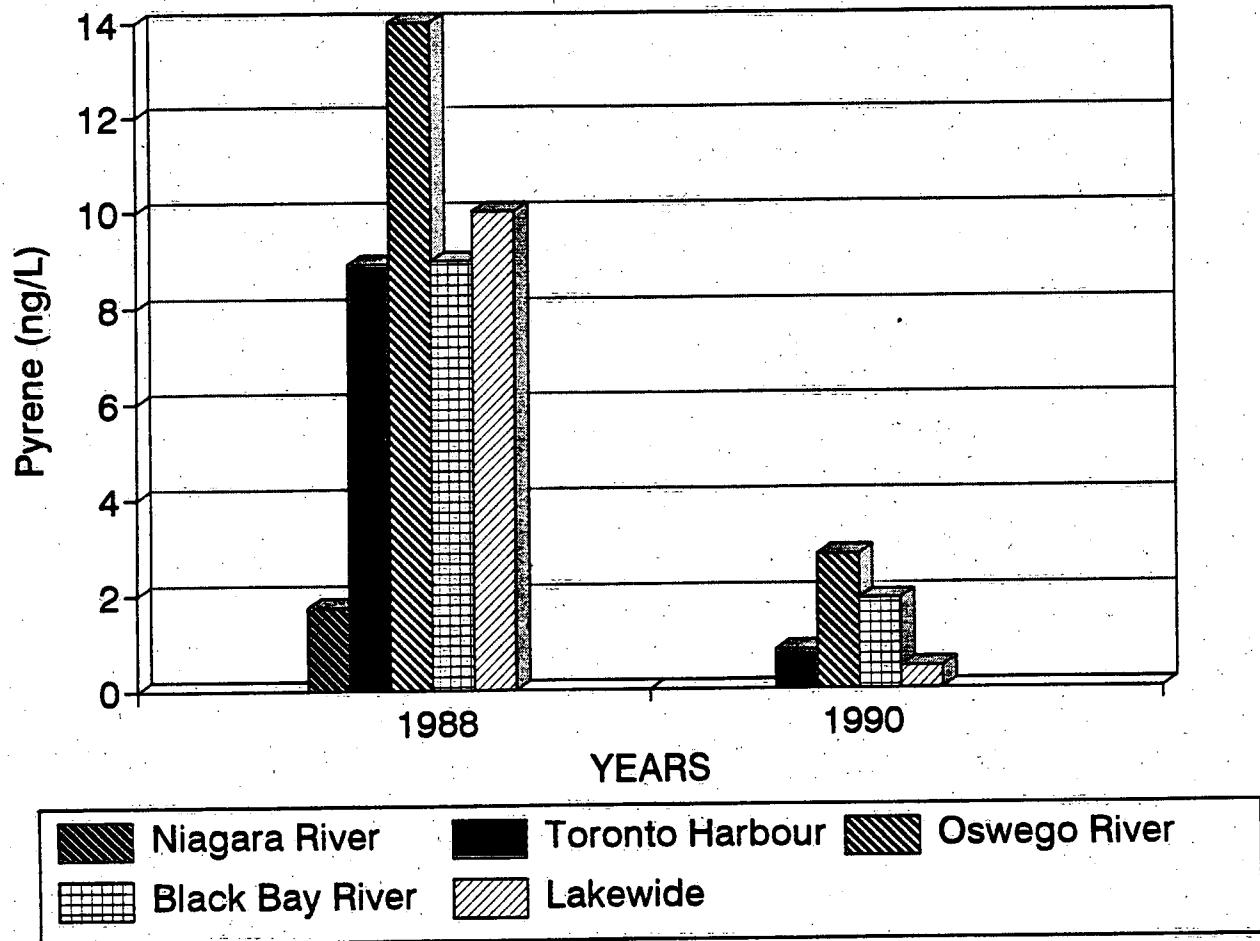


Fig. 15 Mean pyrene concentrations for Lake Ontario 1988-1990.

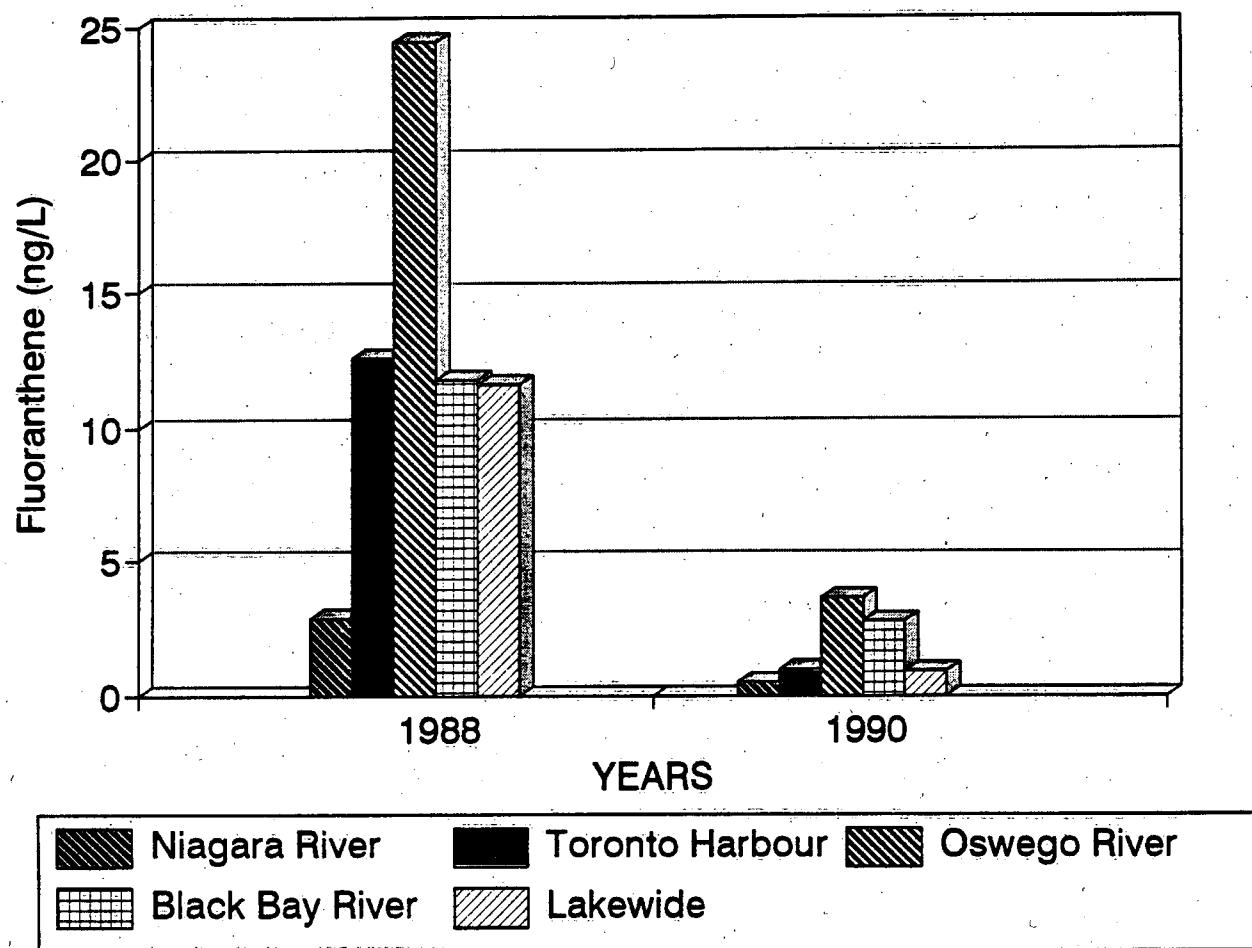


Fig. 16 Mean fluoranthene concentrations for Lake Ontario 1988-1990.

3.6 Hamilton Harbour

The data for Hamilton Harbour was limited to 5 stations for 1988 and 1990 and showed a very large variance. Mean concentrations are summarized in Table 8. In most cases, the levels observed in Hamilton Harbour were higher than in Lake Ontario.

3.6.1 Organochlorine pesticides

Alpha-BHC, lindane, heptachlor-epoxide, alpha-chlordanne, p,p'-DDE, alpha- and beta-endosulfan and dieldrin were detected in Hamilton Harbour in 1988, but in 1990 only the BHC isomers and dieldrin were found.

In 1988 and 1990, mean concentrations of lindane in Hamilton Harbour were respectively ten and thirty times higher than the lakewide means. Lindane's concentration were higher than alpha-BHC's in the harbour (Fig. 17). While the alpha-BHC mean levels decreased from 1988 to 1990, lindane's increased significantly. A fire in a factory that processed lindane in Grimsby was reported a few years ago.

3.6.2 Total polychlorinated biphenyls

PCBs were detected at a few stations in Hamilton Harbour in 1988 and 1990. They ranged from 0.84 to 2.69 ng/L.

3.6.3 Chlorobenzenes

Dichlorobenzenes were widespread in Hamilton Harbour in both years studied, and their mean concentrations (total) were about ten times higher than the lakewide levels. 1,2,3- and 1,2,4-trichlorobenzene concentrations were also ubiquitous. 1,3,5-trichlorobenzene and 1,2,3,4-tetrachlorobenzene were detected, but at relatively low levels (Fig. 18).

3.6.4 Polynuclear aromatic hydrocarbons

In 1988, the valid data was limited to station # 108, where all PAHs tested were found, except for 2-chloronaphthalene and 1,2,3,4-tetrahydronaphthalene. All PAHs analyzed were detected in 1990. Fluoranthene concentrations showed a large variance, ranging from 58.13 to 394.60 ng/l.

Table 8. Hamilton Harbour 1988 and 1990 organic contaminants studies.

Parameter	Detection Limits	Values >P.D.L.	No. Samples	Mean Conc. (ng/l)	Standard Deviation	C.I. Conc. (ng/l) Minimum	Maximum
1988							
Alpha-BHC	.300	5	5	1.912	.9374E-01	1.764	2.072
Lindane	.140	5	5	9.180	1.215	7.389	11.41
Heptachlor-Epoxide	.200E-01	3	5	0.19954	Unbiased Estimate		
Dieldrin	.500E-01	5	5	.2398	.4073E-01	.1815	.3168
Beta-Endosulfan	.600E-01	4	5	.1029	.3485E-01	.5573E-01	.1693
1,3-DCB	.300	4	5	.6768	.2323	.3634	1.120
1,4-DCB	.510	4	5	7.704	6.558	1.327	21.66
1,2-DCB	.580	4	5	1.994	.7518	1.001	3.447
Total DCBs	.300	4	5	17.33	23.08	.8040	63.42
135-TCB	.200E-01	4	5	.2313E-01	.3429E-02	.1794E-01	.2918E-01
124-TCB	.240	4	5	25.93766	Unbiased Estimate		
123-TCB	.900E-01	4	5	7.87186	Unbiased Estimate		
1234-TeCB	.900E-01	4	5	.1989	.5691E-01	.1195	.3053
1990							
Alpha-BHC	.300	4	5	.8176	.3028	.4158	1.401
Lindane	.140	4	5	15.54	26.12	.2400	59.58
1,3-DCB	.300	3	5	.3440	.4292E-01	.2782	.4188
1,4-DCB	.510	4	5	9.89214	Unbiased Estimate		
Total DCBs	.300	4	5	11.01658	Unbiased Estimate		
124-TCB	.240	4	5	5.790	5.606	.7405	17.73
123-TCB	.900E-01	4	5	2.340	2.331	.2781	7.298
1234-TeCB	.900E-01	3	5	.2109	.1060	.8153E-01	.4239
Indene	.200	5	5	204.0	184.4	46.31	898.2
1234-THNP	.250	5	5	2.486	1.069	1.228	5.033
2-Methylnaphthalene	.260	5	5	50.10	42.94	12.29	204.3
1-Methylnaphthalene	.280	5	5	29.06	23.43	7.745	109.0
Acenaphthylene	.190	5	5	45.50	28.89	16.07	128.9
Acenaphtene	.300	4	5	12.01105	Unbiased Estimate		
Fluorene	.190	4	5	20.09943	Unbiased Estimate		
Phenanthrene	.130	5	5	114.5	87.62	32.66	401.6
Pyrene	.320	5	5	90.43	27.18	55.24	148.0
Fluoranthene	.350	5	5	150.1	44.25	92.53	243.4
Benzo(K/B) Fluoranthene	.490	5	5	24.77	6.192	16.44	37.32
Benzo(A) Pyrene	.460	5	5	23.08	8.439	12.67	42.04
Indeno(1,2-CD) Pyrene	.260	5	5	13.38	3.216	9.020	19.84
Benzo(GHI) Perylene	.230	3	5	0.63076	Unbiased Estimate		

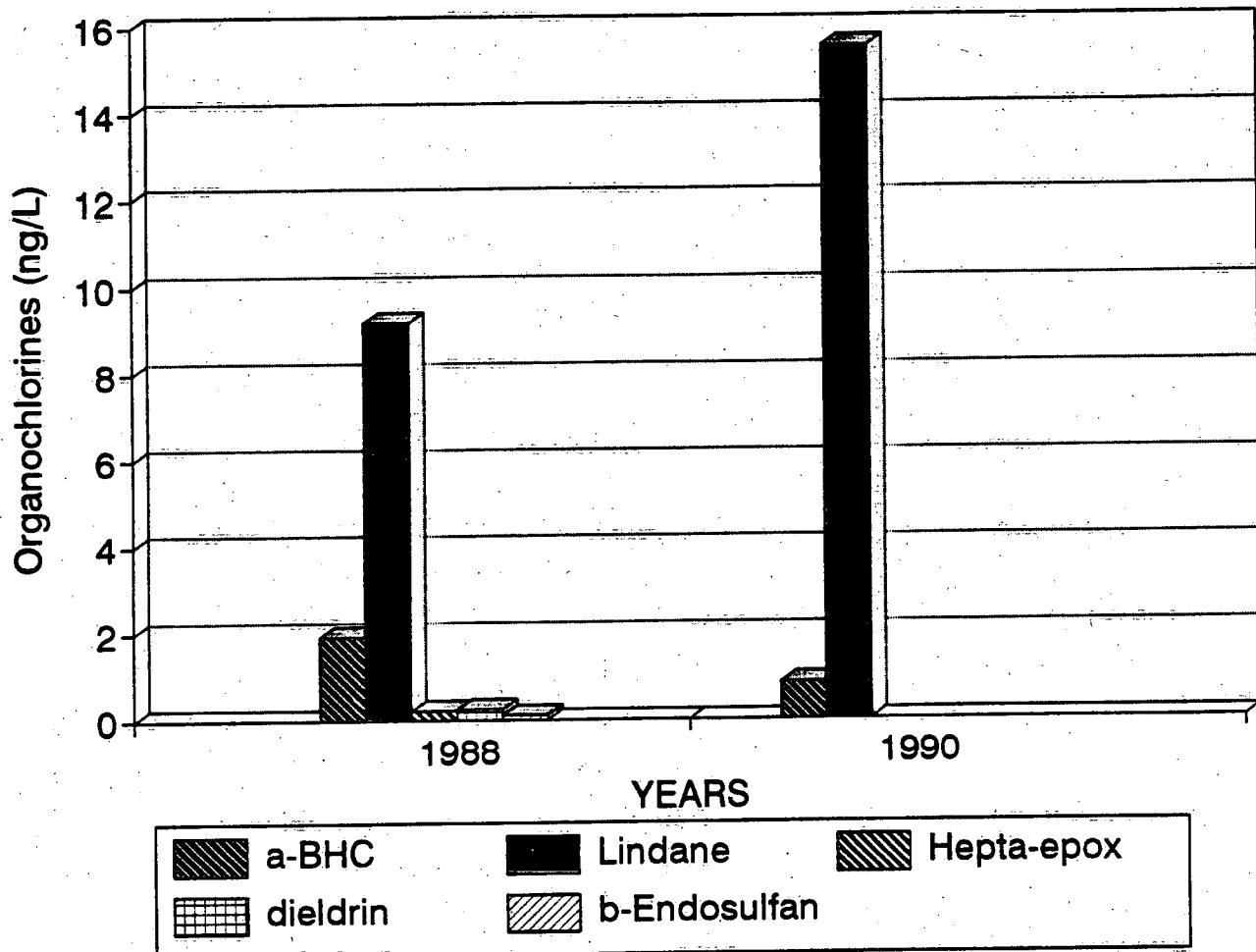


Fig. 17 Mean organochlorine concentrations for Hamilton Harbour 1988-1990.

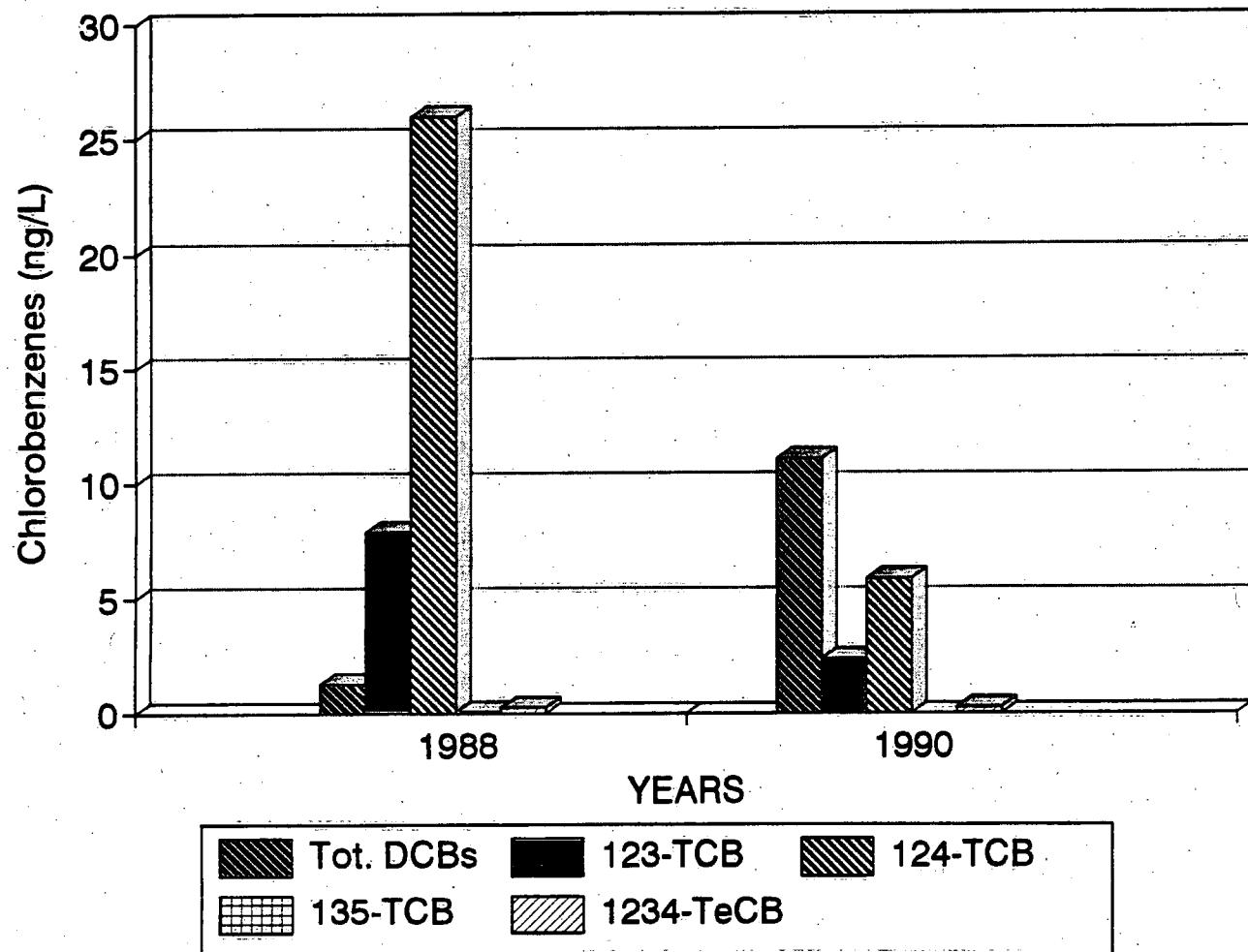


Fig. 18 Mean chlorobenzene concentrations for Hamilton Harbour 1988-1990.

4. DISCUSSION

Differences between lakes have been assessed for the toxics for which lakewide mean concentrations were computed by the MLE method. The concentrations have been compared to the most stringent and enforceable water quality criteria for human health and aquatic resource protection (Table 9) as developed by the United States Environmental Protection Agency (USEPA), the New York State Department of Environmental Conservation (NYSDEC), the International Joint Commission (IJC), the Ontario Ministry of the Environment (MOE) and Health and Welfare Canada (HWC). These numerical values, often defined as maximum acceptable limits for individual parameters, are meant to restore and maintain different uses of water in the Great Lakes.

4.1 Organochlorine pesticides

Overall alpha-BHC lakewide concentrations decreased in all Great Lakes from 1986 to 1990, except for Lake Superior, where a maximum of 14.62 ng/L was reported in 1987 (Fig. 19). In 1986, the aquatic resource protection (NYSDEC) criterion for alpha-BHC (10 ng/l) was slightly exceeded at station # 67 in Lake Huron (10.85 ng/L), in the Detour Passage. On Lake Superior, exceedences occurred at 12% and 62% of the stations studied in 1986 and 1987, respectively. The minimum concentration was recorded in 1990 in Hamilton Harbour. A decreasing gradient from north to south is observed throughout the lakes. Levels measured near Thompson Island and Grand Marais (stations # 140 and 177) were lower than those recorded downstream of Thunder Bay where the highest levels were found near Marathon, Jackfish Bay and at the south-east end of Simpson Island (stations # 89, 100 and 105).

The highest lindane mean concentrations were computed for Hamilton Harbour in 1988 (9.18 ng/L) and 1990 (15.54 ng/L) (Fig. 20). The mean lakewide concentrations ranged from 0.33 to 1.38 ng/L for Lake Ontario. The criterion for aquatic resource protection (10 ng/L) was exceeded in Hamilton Harbour at station # 108 in 1988 (14.9 ng/L), and at station # 107 in 1990 (20.45 ng/L).

Lindane was used in the western provinces for the treatment of seeds and soils. The technical grade pesticide, which is a mixture of BHC isomers, shows an alpha:gamma-BHC ratio of 5:1. Lindane, which is the active isomer, is known to be highly volatile. Prevailing westerly winds could be carrying volatilized molecules from the soil along that axis throughout the lakes. The overall lakewide alpha:gamma-BHC ratio ranged from 3 to 5:1. In Hamilton Harbour, this ratio was reversed and was close to 1:10, suggesting the proximity of a source of lindane. Since the 1970's, their use has been restricted and their persistence, coupled to continued inputs via atmospheric deposition, explains their detection across the Great Lakes (Stevens and Neilson, 1989).

Table 9 Most stringent water quality criteria (enforceable) for human health (HH) and aquatic resource protection (ARP).

PARAMETER	CRITERIA (ng/L)	CRITERIA TYPE	AGENCY
Alpha-BHC	10.0	ARP	NYSDEC
Lindane	10.0	ARP	MOE
Heptachlor	1.0	ARP	MOE, IJC, NYSDEC
Aldrin	1.0	HH	MOE, IJC, NYSDEC
Heptachlor-Epoxide	1.0	ARP	MOE, IJC, NYSDEC
Total Chlordane (Alpha+Gamma)	2.0	HH	NYSDEC
Endosulfan (Alpha+Beta)	3.0	ARP	MOE
PP/DDE	10.0	HH	NYSDEC
Dieldrin	1.0	ARP	MOE, IJC, NYSDEC
Endrin	2.0	ARP	MOE, IJC, NYSDEC
OP/DDT	1.0 ¹	ARP	HWC, NYSDEC
PP/DDD	1.0 ¹	ARP	HWC, NYSDEC
PP/DDT	1.0 ¹	ARP	HWC, NYSDEC
Mirex	1.0	ARP	MOE, USEPA, NYSDEC
Methoxychlor	30.0	ARP	NYSDEC
Total Polychlorinated Biphenyls	1.0	ARP	MOE, NYSDEC
1,3-Dichlorobenzene (M)	2500.0	ARP	MOE
1,4-Dichlorobenzene (P)	4000.0	ARP	MOE
1,2-Dichlorobenzene (O)	2500.0	ARP	MOE
1,3,5-Trichlorobenzene	650.0	ARP	MOE
1,2,4-Trichlorobenzene	500.0	ARP	MOE
1,2,3-Trichlorobenzene	900.0	ARP	MOE
1,2,3,4-Tetrachlorobenzene	100.0	ARP	MOE
Pentachlorobenzene	30.0	ARP	MOE
Hexachlorobenzene	6.5	ARP	MOE
Fluoranthene	50000.0	HH	NYSDEC
Benzo (B/K) Fluoranthene	2.0	HH	NYSDEC
Benzo (A) Pyrene	1.2	HH	NYSDEC
Indeno (123-CD) Pyrene	2.0	HH	NYSDEC
Benzo (GHI) Perylene	--	--	--
Indene	--	--	--
1,2,3,4-Tetrahydronaphthalene	--	--	--
Methylnaphthalene-1	--	--	--
Methylnaphthalene-2	--	--	--
2-Chloronaphthalene	10000.0	HH	NYSDEC
Acenaphtene	20000.0	HH	NYSDEC
Acenaphthylene	--	--	--
Fluorene	50000.0	HH	NYSDEC
Phenanthrene	50000.0	HH	NYSDEC
Pyrene	50000.0	HH	NYSDEC

¹ : DDT and metabolites.

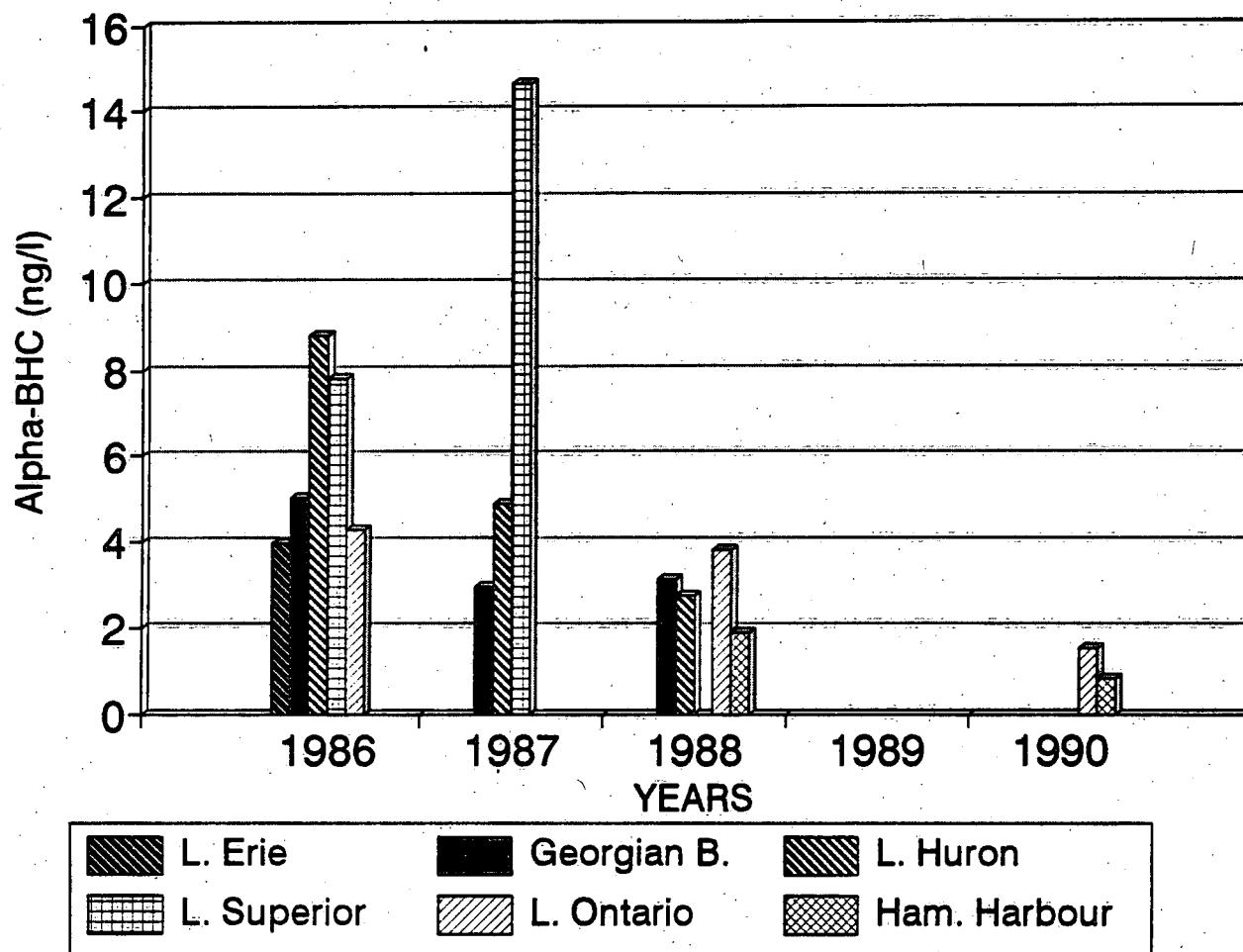


Fig. 19 Mean alpha-BHC lakewide concentrations for the Great Lakes 1986-1990.

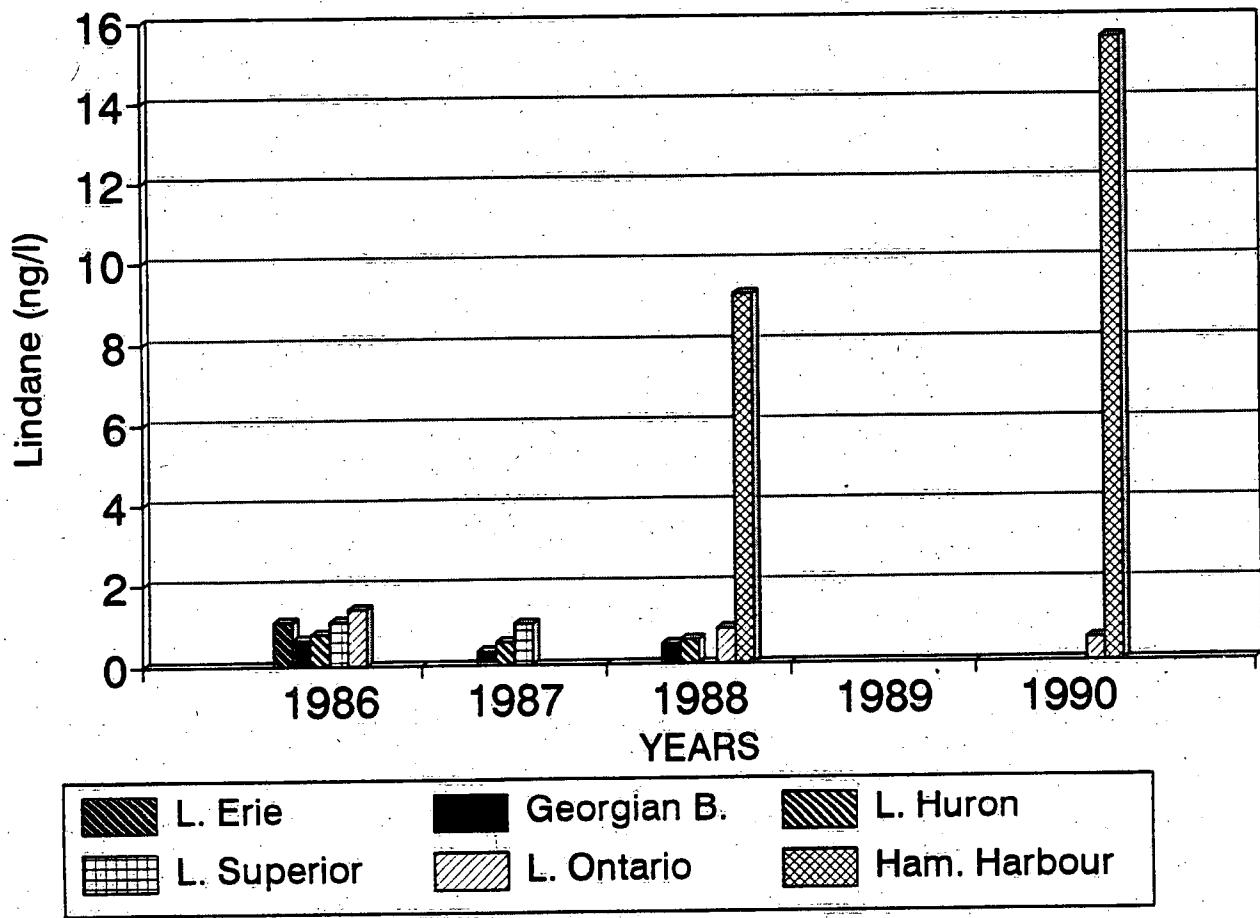


Fig. 20 Mean lindane lakewide concentrations for the Great Lakes 1986-1990.

Dieldrin mean lakewide concentrations were comparable from one lake to another, as well as in Hamilton Harbour (Fig. 21). Aldrin is converted via oxidation to dieldrin, a toxic metabolite. Both were banned in Ontario (1969) and in the U.S. (1974), but dieldrin is persistent in the aquatic environment ranging from 0.21 to 0.39 ng/L over the period studied. In 1986, dieldrin exceeded the aquatic resource protection (NYSDEC) criterion (1 ng/l) in Lake Erie at station # 281, at the mouth of the Sandusky River (1.11 ng/L).

Heptachlor was not found in any studies. It undergoes hydrolysis and a minor product of its biological transformation becomes heptachlor-epoxide. Concentrations of this metabolite were also spatially and temporally uniform (Fig. 22), demonstrating its persistence in the aquatic environment. The means varied between 0.08 and 0.25 ng/L.

DDT and its metabolites were detected in several locations on Lake Ontario in 1986 and 1988, but not in 1990. Mirex was not observed in any of the lakes throughout the study period.

Mirex had not been detected in Lake Ontario in other previous studies (McCrea *et al.* 1985, Biberhofer *et al.* 1986, Thomas *et al.*, 1988). Mirex and alpha-endosulfan were found at Niagara-on-the-Lake in the 1986-1987 Niagara River Upstream/Downstream Monitoring Program (Data Interpretation Group, 1988).

In a independent study undertaken in April 1991 (Backus *et al.*, 1992), p,p'-DDT, p,p'-DDE, mirex, alpha-chlordane, heptachlor-epoxide, dieldrin and endrin were found in Lake Ontario at a station influenced by the outflow of the Niagara River. Reported mean alpha-BHC concentration (1.4 ng/L) for ambient waters was similar to that of Lake Ontario's 1990 spring survey (1.53 n/L).

The St. Lawrence River Monitoring Program reported mean annual concentrations for alpha-BHC and lindane in 1990 (1.56 and 0.44 ng/L, respectively) (Biberhofer, pers. comm.) comparable to the lakewide levels (1.53 and 0.59 ng/L) measured in Lake Ontario's 1990 spring survey.

The Niagara and Oswego Rivers, and Toronto and Hamilton Harbours are sources of organochlorines to Lake Ontario (cf sections 3.5.1 and 3.6.1).

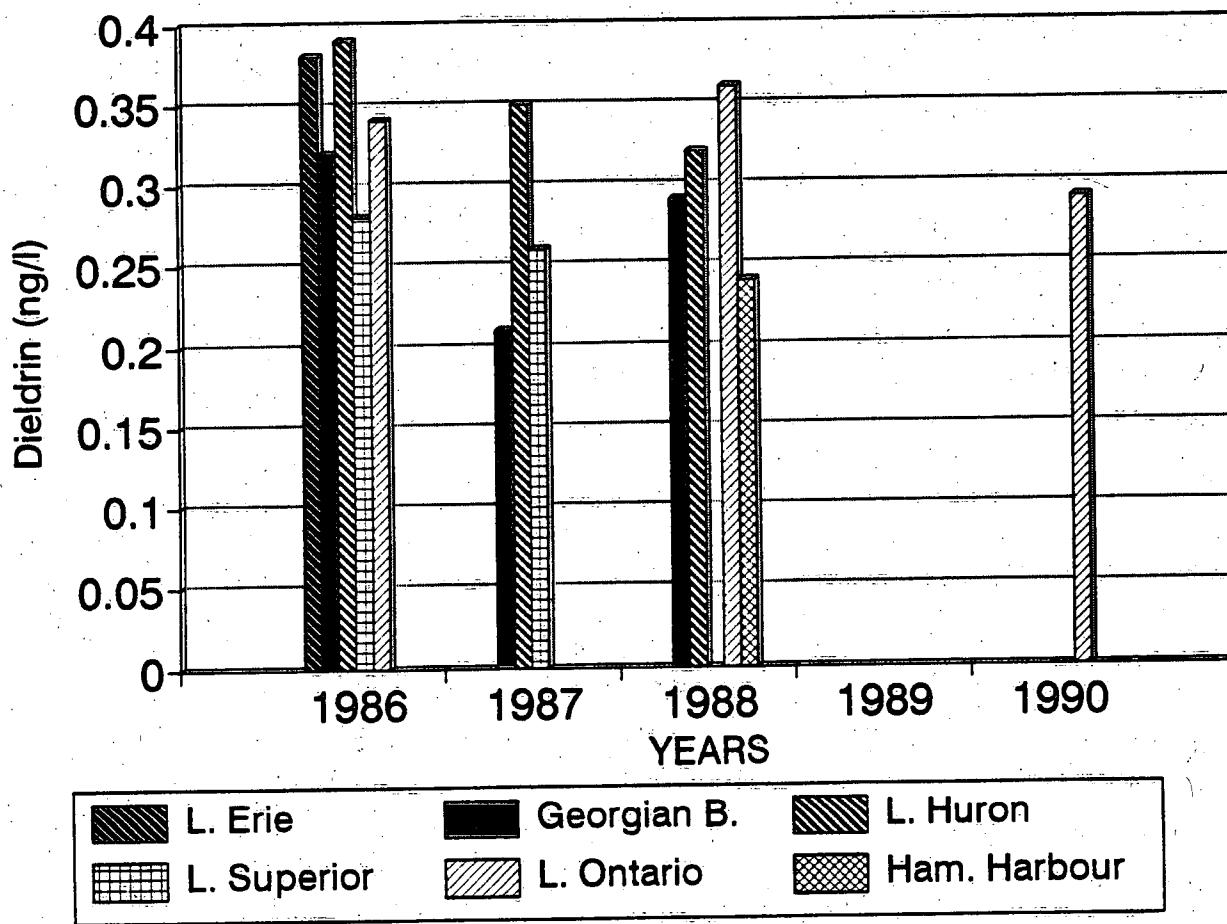


Fig. 21 Mean dieldrin lakewide concentrations for the Great Lakes 1986-1990.

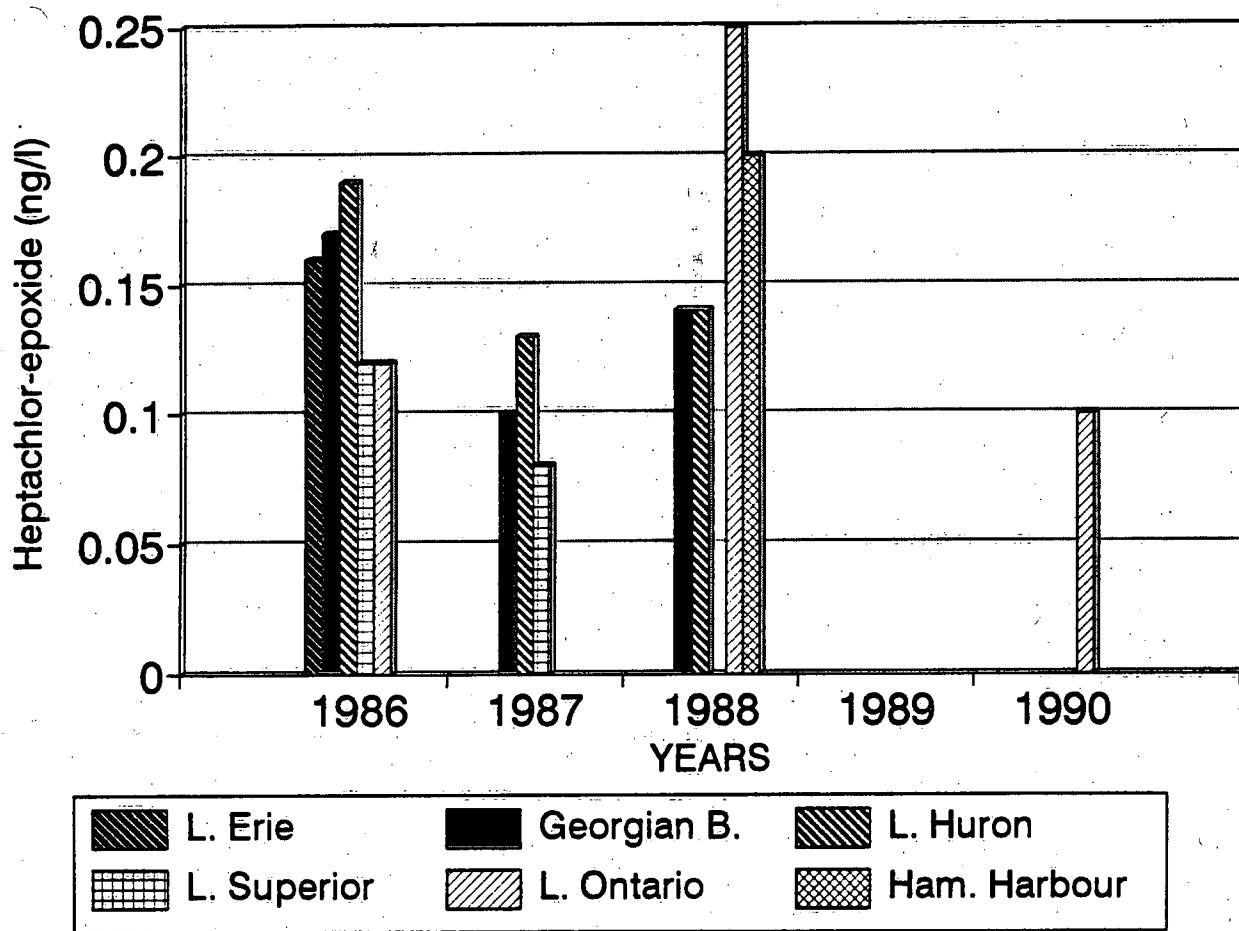


Fig. 22 Mean heptachlor-epoxide lakewide concentrations for the Great Lakes 1986-1990.

4.2 Total polychlorinated biphenyls

Production of PCBs in the U.S. ceased in 1977. They were used in electrical capacitors and transformers, vacuum pumps, gas-transmission turbines, hydraulic fluids, plasticizers, adhesives, flame retardants, inks and lubricants. In Canada, their use was banned in the 1980's and phasing out of the utilities already in use was planned. Large amounts are still stored in containers across the country, awaiting appropriate disposal. Several non-point sources provide inputs to the Great Lakes via atmospheric deposition (Chan, 1989).

Mean lakewide PCB concentrations found in Lake Erie were similar to those in Lake Ontario in 1986, while Lake Huron's were about half (Fig. 23). The lakewide concentrations for Lake Superior in 1987 were comparable to Lake Huron's 1986 figures. In 1988, the PCB levels in Georgian Bay were higher than those in Lake Huron. For the period studied (1986-1990), concentrations in the Lower Lakes ranged from 0.9 to 1.22 ng/L while those of the Upper Lakes varied between 0.55 and 0.9 mg/L, when excluding the 1988 Georgian Bay numbers. Previous studies reported levels ranging from 0.3 to 3.1 ng/L (Simons *et al.* 1985, Murthy *et al.* 1984).

In Lake Erie, concentrations recorded in 1986 exceeded the aquatic resource protection (NYSDEC) criterion of 1 ng/l at these locations at the mouth of the Detroit, Maumee and Grand Rivers, and near Buffalo: # 212, 213, 214, 215, 226, 227, 228, and 281.

In Lake Superior, the criterion was exceeded in 1987 at stations # 130 (south-east end of Isle Royale) and # 164 (near Fourteen Mile Point, south shore).

Exceedences were recorded in Saginaw Bay at station # 101 in 1986 (2.34 ng/L) and in 1987 (1.79 ng/L). In Lake Huron, the criterion was also exceeded in 1986 in the open waters (station # 54 (1.42 ng/L)), in the Straits of Mackinac (station # 65 (1.66 ng/L)), and near Pointe aux Barques (station # 17 (1.15 ng/L)) in 1987. In 1988, exceedences were measured in the Detour Passage (station # 67 (1.36 ng/L)), and at all stations monitored in Georgian Bay, including Nottawasaga Bay. The criterion was also exceeded in the Saginaw Bay (stations # 100 (3.57 ng/L), and # 101 (1.54 ng/L)) and in the Straits of Mackinac (stations # 64 (1.08 ng/L), and # 102 (1.03 ng/L)). Lake Michigan and Saginaw Bay are sources of PCBs to Lake Huron.

In Lake Ontario, exceedences were measured at about 50% of the stations from 1986 to 1990. Very high concentrations of PCBs were recorded at locations influenced by the Niagara River and the Black River Bay. Overall maximum concentrations were reported in the Black River Bay area. Mean annual concentrations of PCBs have increased from 1986-87 to 1989-90 at the Niagara-on-the-Lake station (Data Interpretation Group, 1983 and 1992). Niagara River

and Black River Bay are major sources of PCBs to Lake Ontario.

In 1988, the criterion was exceeded in Hamilton Harbour at station # 108 (2.69 ng/L), and at station # 104 in 1990 (1.42 ng/l). A separate study carried out at several sites in Hamilton Harbour (Fox, 1990) estimated mean levels of PCBs at 16 ng/L in 1988, and 24 ng/L in 1989. Hamilton Harbour is a source of PCBs to Lake Ontario.

4.3 Chlorobzenenes

Chlorobzenenes are still manufactured within the Great Lakes basin. They are widely used and found in liquid and solid industrial wastes, atmospheric discharges and municipal wastewaters. Their fate and distribution in the aquatic environment is regulated by their volatilization and sorption to sediments. As their degree of chlorination and molecular weight rises, their volatility decreases and their octanol-water partition coefficients (K_{ow}) increases (Stevens and Neilson, 1989).

The maximum levels for total dichlorobzenenes were recorded in Hamilton Harbour as they were ten times higher than those of Lake Ontario. An extreme concentration was observed at the mouth of Oswego River in 1988. Total DCB levels in Lake Erie were lower than in Lake Ontario. The mean concentrations measured in the Upper Lakes were lower than those of the Lower Lakes (Fig. 24).

Concentrations of dichlorobzenenes (1 to 5 ng/L) measured at the mouth of the Detroit River identified it as a source to Lake Erie. Pentachlorobenzene (0.05 ng/L) was detected at the mouth of the Detroit River (station # 212).

Lake Ontario showed the highest chlorobzenenes levels of all the lakes. All forms of chlorobzenenes detected in Lake Ontario's 1988 and 1990 spring surveys were higher than the annual means observed at Wolfe Island in 1989 and 1990 (Biberhofer, pers. comm., St. Lawrence River Monitoring Program).

High levels of chlorobzenenes in the Niagara River plume and out of Hamilton Harbour identify them as sources to Lake Ontario.

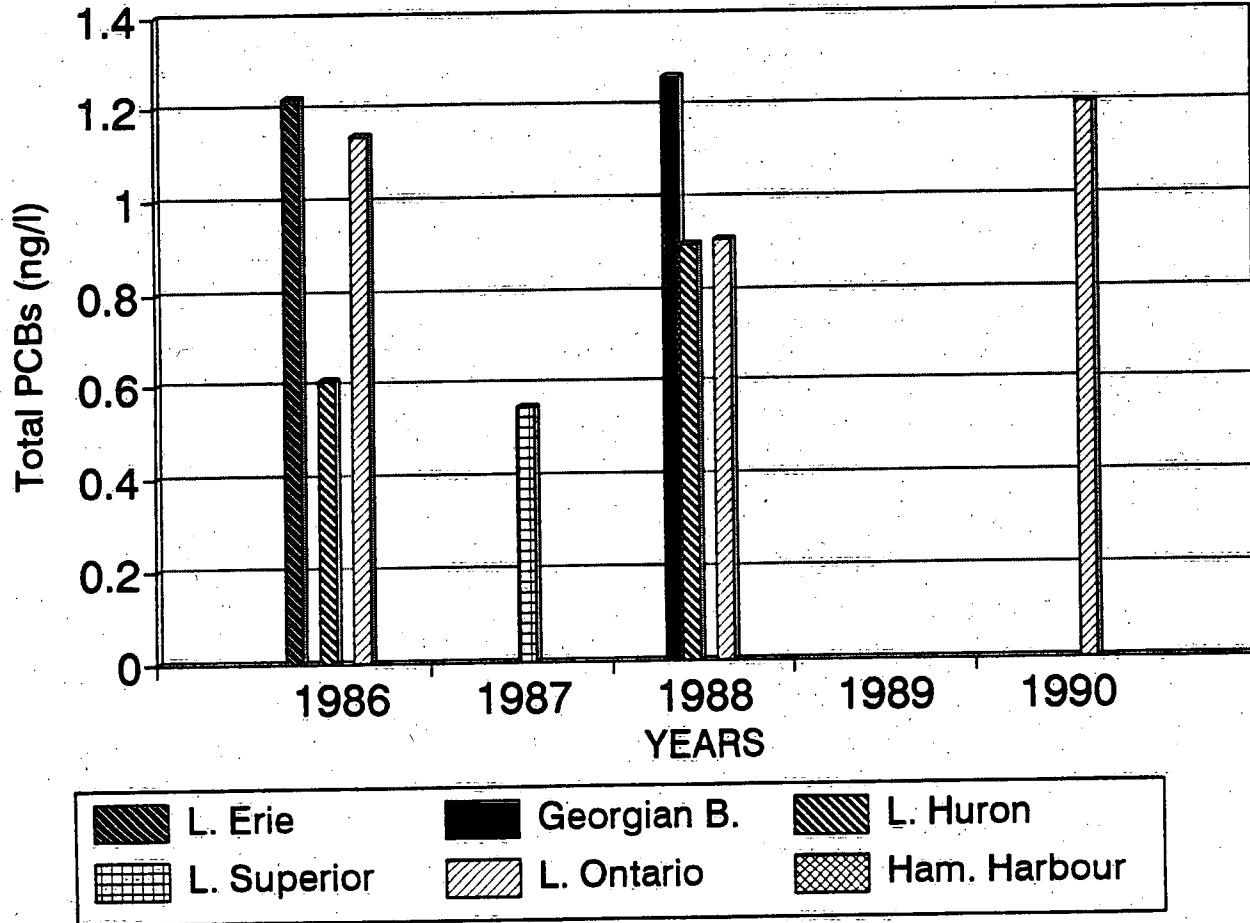


Fig. 23 Mean total PCB lakewide concentrations for the Great Lakes 1986-1990.

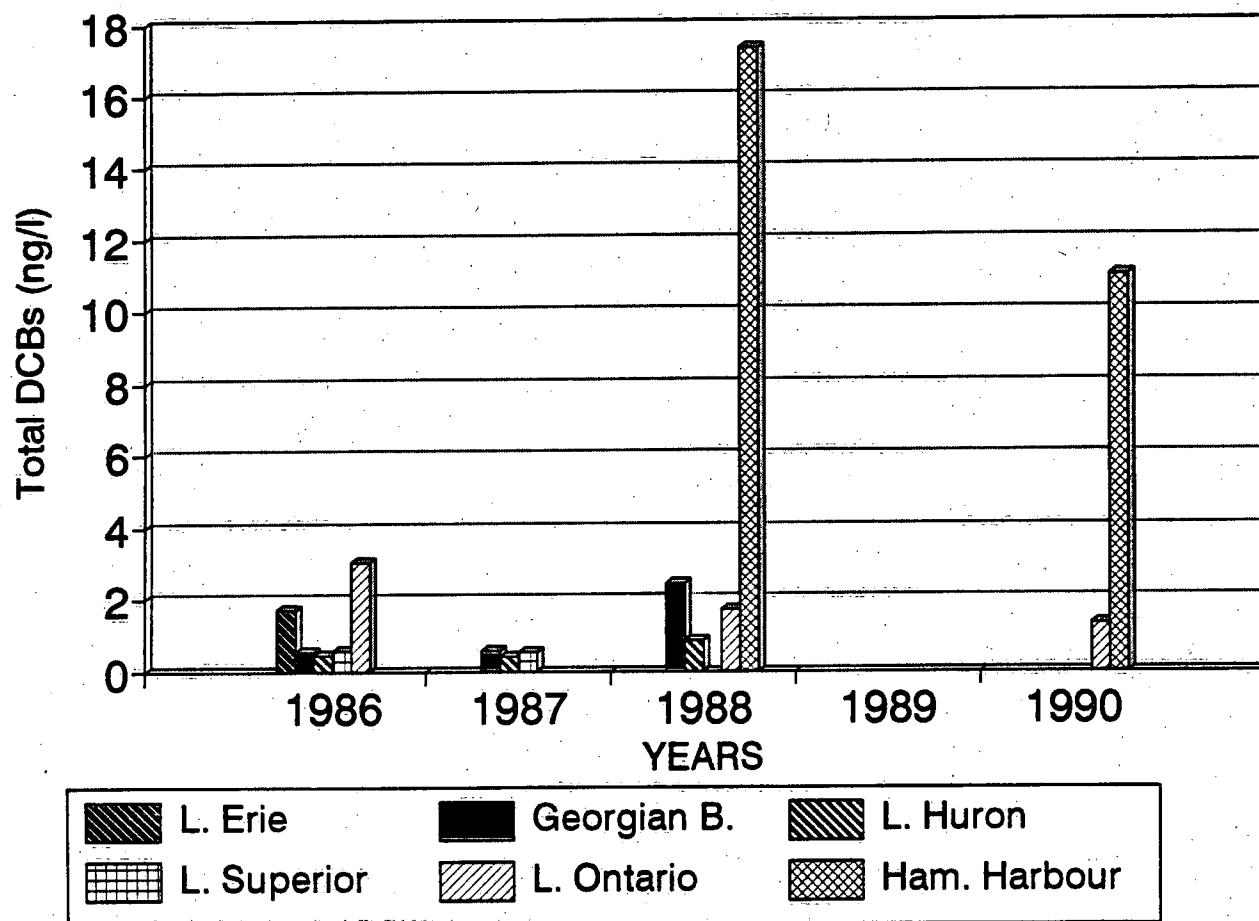


Fig. 24 Mean total dichlorobenzene lakewide concentrations for the Great Lakes 1986-1990.

4.4 Polynuclear aromatic hydrocarbons

PAHs are present in coal tar and crude oil. They are potentially produced in petroleum refining processes. They are byproducts of coking processes and the combustion of organic materials including fossil fuels and forest fires. One can expect to detect substantial PAH concentrations in the vicinity of densely populated and industrialized areas. Combustion of hydrocarbons by automobiles, domestic heating and industries such as foundries release PAHs in the atmosphere that are eventually deposited in the aquatic environment. "The most common concern with PAHs is their potential to induce cancer in wildlife at concentrations below the acute toxicity concentration", as is the case in Hamilton Harbour where the removal of these substances is recommended (Murphy, 1990).

Concentrations of benzo(K and/or B)fluoranthene (2.0 ng/L), benzo(A)pyrene (1.2 ng/L) and indeno(1,2,3-CD)pyrene (2.0 ng/L) exceeded their respective criterion in 1988 and 1990 at the majority of stations in Hamilton Harbour.

At Niagara-on-the-Lake, the mean annual concentrations of fluoranthene and pyrene for 1989-1990 (Data Interpretation Group, 1992) were higher than the lakewide means reported in the Lake Ontario spring 1990 survey. The mean concentrations of fluoranthene in Lake Ontario were about six times higher than those found in Lake Huron in 1988 (Fig. 25).

The maxima overall PAHs concentrations were measured in Hamilton Harbour. Concentrations recorded in 1990 at station # 3 near Grimsby were also very high. A study undertaken in July 1990 in Hamilton Harbour's ship canal demonstrated high levels of PAHs (Fox, 1990).

The Niagara River, Hamilton Harbour, Black River Bay, Toronto Harbour, Oswego River are sources of PAHs to Lake Ontario (Fig. 14 to 16).

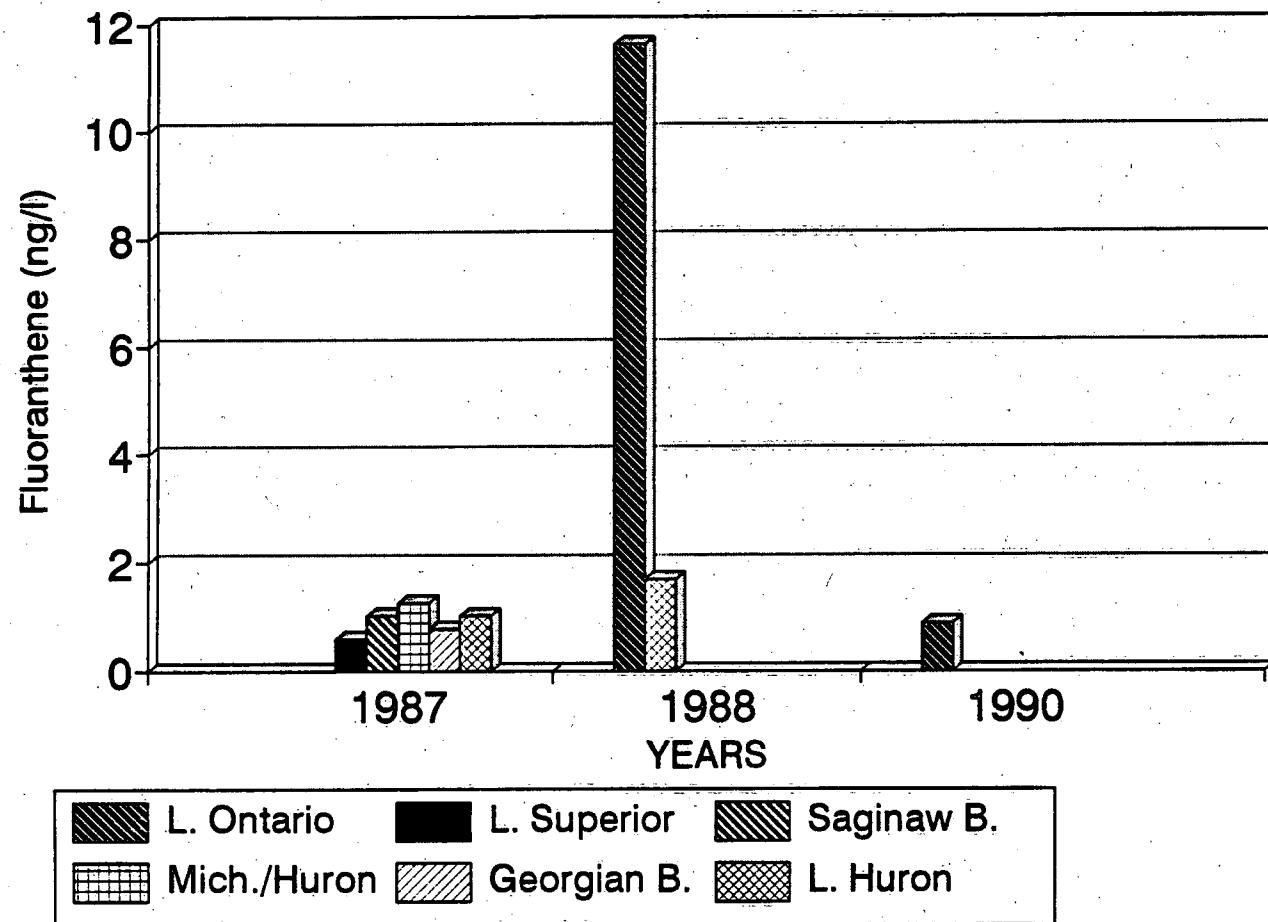


Fig. 25 Mean fluoranthene lakewide concentrations for the Great Lakes 1987-1990.

4.5 Fate of toxics

The data reported in this paper is about whole water samples collected in the spring isothermal conditions. Time trends and spatial (inter- and intralake lake) distribution of organic contaminants in surface waters can be assessed, as well as their compliance to regulation protecting aquatic life and human health. It is also useful in identifying areas of inputs of toxics within each lake.

The Great Lakes Water Quality Agreement is currently promoting new integrated approaches. The fate of toxics and their interactions with the ecosystem need to be understood more clearly. Hence the Lake Ontario Toxics Management Plan, based on a chemical-by-chemical approach, is shifting towards a Lakewide Management Plan that is ecosystem oriented. "Annex II of the 1987 Protocol specifies that the surveillance program allow assessment of "total pollutant loadings to, storage and transformation within, and export from the Great Lakes System", i.e. the mass balance approach" (Mass Balance Workshop Steering Committee, 1990).

Mass balance models quantify load-concentration relationships for key environmental compartments and determine target load reduction. The existing surveillance program was not designed to measure loadings and other data required to validate and improve mass balance models. In order to understand the nutrient-contaminant interactions, filtered, unfiltered and particulate concentrations throughout the water column have to be measured. In addition, it is important to measure the critical sorbent-related parameters, in order to understand these interactions: particulate and dissolved organic carbon, Chlorophyll a, total suspended sediments, particulate calcium, iron, aluminium and manganese (Mass Balance Workshop Steering Committee, 1990). It was recommended that stations representative of each of the homogeneous zones of each lake be monitored, as well as the seasonal and stratification effects on contaminant distribution (Great Lakes Program, 1993).

5. SUMMARY

In 1986, alpha-BHC concentrations were exceeding the aquatic resource protection criterion near Jackfish Bay and at the south-east end of Simpson Island on the north shore of Lake Superior, while exceedences were widespread in 1987. On Lake Huron, an exceedence was recorded in 1986 at the mouth of the Detour Passage (north-west end). Lakewide means in Lake Huron were lower than Lake Superior's. In 1986, Lake Erie's concentrations were comparable to Lake Ontario's, as no exceedence occurred in the Lower Lakes. This decreasing gradient from north to south suggests the atmosphere as a potential source of alpha-BHC to Lake Superior.

The only exceedences to the aquatic resource protection criterion for lindane were recorded in Hamilton Harbour in 1988 and 1990. For all lakes, the alpha-BHC concentrations were higher than lindane's, but in Hamilton Harbour, this ratio was reversed.

Dieldrin's criterion for aquatic resource protection was exceeded at one location only, at the mouth of the Sandusky River on Lake Erie in 1986.

p,p'-DDT was detected exclusively in Lake Ontario in 1988 in the Toronto region. In 1986, p,p'-DDE was detected at the west end of Lake Erie, near Monroe and Toledo. In Lake Ontario, p,p'-DDE was detected in 1986 at Port Dalhousie, near the Welland Canal, near Wilson, N.Y., near Port Weller Harbour and at Oswego River's mouth. In 1988, p,p'-DDE was found near Kingston, at the mouth of Niagara River, near Port Weller Harbour, in the Black River Bay, at the mouth of Oswego River and in Hamilton Harbour. In 1990, DDT/DDE were not detected at any location on Lake Ontario.

Some areas releasing organochlorine pesticides to Lake Ontario were Niagara and Oswego Rivers; Black River Bay; Port Weller; Hamilton, Toronto and Kingston Harbours; and Welland Canal. The Maumee, Detroit and Sandusky Rivers were sources of organochlorines to Lake Erie.

Alpha-BHC, lindane, heptachlor-epoxide and dieldrin were ubiquitous. Generally, the concentrations of organochlorine pesticides decreased from 1986 to 1990, the highest overall being measured in Lake Ontario.

PCBs were widespread from 1986 to 1990. Total PCB concentrations were higher in the Lower Lakes than in the Upper Lakes. Although point and diffuse sources have been identified, atmospheric deposition is a major input source of PCBs to the Great Lakes (Great Lakes Mass Balance Workshop, 1991; Chan and Perkins, 1989).

The PCB criterion for the protection of aquatic resource was exceeded in 1986 at the west end of Lake Erie, at the mouth of the Detroit and Sandusky Rivers. Exceedences were also recorded at the east end, near Buffalo, and at the mouth of the Grand River.

In Lake Superior, the criterion for PCB was exceeded in 1987 at the south-east end of Isle Royale and on the south shore, near Fourteen Mile Point.

Excessive concentrations of PCB were recorded in Saginaw Bay in 1986, 1987 and 1988. In 1986, exceedences occurred in the Straits of Mackinac and at the east end of Lake Huron, and in 1987, on the south shore close to Pointe aux Barques. In 1988, exceedences were ubiquitous in Georgian Bay including Nottawasaga Bay, and were also found in the Straits of Mackinac and Saginaw Bay. Saginaw and Georgian Bays, as well as Lake Michigan, contributed PCBs to Lake Huron.

In Lake Ontario, exceedences for PCBs were measured at about half the stations monitored from 1986 to 1990. The Niagara River and the Black River Bay, where maximum PCB concentrations were measured, were major sources of PCBs to Lake Ontario. Exceedences were observed in Hamilton Harbour, also identified as a source of PCBs to the lake.

Total dichlorobenzene concentrations were higher in the Lower Lakes, Lake Ontario's being the highest overall. Hamilton Harbour's total dichlorobenzenes were ten times higher than Lake Ontario's. High levels of chlorobenzenes were measured at locations influenced by the Niagara River plume. An extreme value was observed at the mouth of the Oswego River in 1988, also identified as a source of dichlorobenzene to the lake.

The maximum PAH concentrations were reported in Hamilton Harbour where exceedences to their respective criterion were measured for benzo(B and/or K)fluoranthene, benzo(A)pyrene and indeno(1,2,3-CD)pyrene at the majority of stations monitored in 1988 and 1990. Outside Hamilton Harbour, the highest overall concentrations of PAHs were recorded in 1990 at station # 3, near Grimsby.

Lake Huron's mean fluoranthene concentrations were six times lower than Lake Ontario's.

The Niagara and Oswego Rivers, Black River Bay, Hamilton and Toronto Harbours were sources of PAHs to Lake Ontario.

6. RECOMMENDATIONS

The surveillance studies from 1986 to 1990 were carried out in order to assess time trends and compliance to chemical specific regulation. Total fraction measurements were sufficient then. Recently, mass balance models for toxics are being developed in order to predict the fate of toxic substances in the lakes, quantify load-concentration relationships for key compartments of the ecosystem and determine target load reductions. Accurate loading estimates from tributaries and other sources of contaminants have to be developed. In order to better understand the dynamics of the ecosystem, particularly the nutrient-contaminant interactions, filtered, unfiltered and particulate fractions throughout the water column have to be measured. The critical sorbent-related parameters required to understand these interactions also need to be measured: particulate and dissolved organic carbon, Chlorophyll a, total suspended sediments, particulate calcium, iron, aluminium and manganese (Mass Balance Workshop Steering Committee, 1990).

Therefore a new approach to monitoring organic contaminants has been adopted and initiated on Lake Ontario in 1992-1993. Large volumes of water are processed in order to separate the dissolved and particulate phases, as done in other programs within the Environmental Quality Branch (Niagara River and St. Lawrence Monitoring Programs). To complete the study, supplementary measurements are made for POC, DOC, and total suspended sediments.

A total of 6 stations, one in each of Lake Ontario's homogeneous water quality zones (Neilson and Stevens, 1985) are monitored over two consecutive years, 1992 and 1993. Stations for which historical data were available were chosen in order to ensure continuity of the trends assessment. Samples are collected in the spring, summer and fall in order to assess seasonal changes in the contaminant concentrations. In spring only epilimnion (surface minus 2m) samples are collected because of existing isothermal conditions. In summer and fall, samples are collected in the epilimnion and in the hypolimnion.

Efforts should be aimed at further studies of the Lower Lakes where the highest contaminant concentrations have been measured. Nearshore locations under the influence of industrialized and densely populated areas should be targeted on. There is a great need to improve and complete loading estimations for the major tributaries of the lakes. Enhancement of the characterization of sediment samples (nature, size, etc...) should be strongly promoted. Offshore locations should be maintained to assess lakewide concentrations. The parameters of interest should remain the organochlorines, chlorobenzenes, PCBs and also PAHs.

Organic contaminant studies should be issue oriented and should involve multiple disciplines such as biology, geology, hydrology and chemistry. In order to implement an integrated approach to the Great Lakes ecosystem, involved authorities should adopt programs such as the Lakewide Management Plan (LaMP) on Lake Ontario or the Lake Superior Initiative. All parties should maintain a high level of inter-communication and collaboration. A common set of guidelines or criteria is strongly recommended to ensure the success of such ecosystemic approaches. Plans specific to each lake should eventually be extended into a Great Lakes basinwide plan such as the GLISP.

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APPENDIX A : STATION LOCATION

Fig. 1 Station location for Lake Superior (1986-1987).

Fig. 2 Station location for Lake Ontario and Hamilton Harbour (1986-1990).

Fig. 3 Station location for Lake Erie (1986).

Fig. 4 Station location Lake Huron and Georgian Bay (1986-1988).

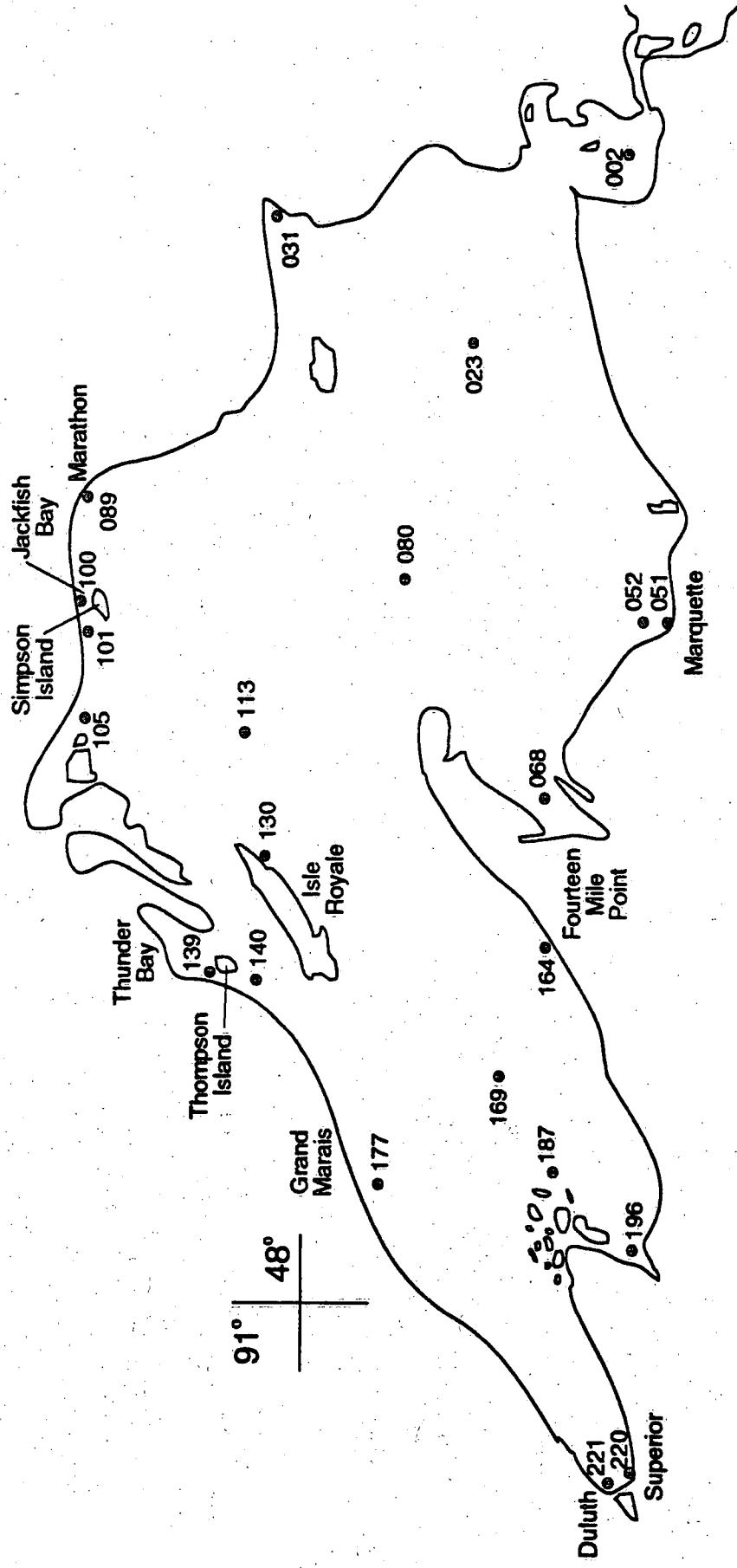


Fig. 1. Station location for Lake Superior (1986 - 1987).

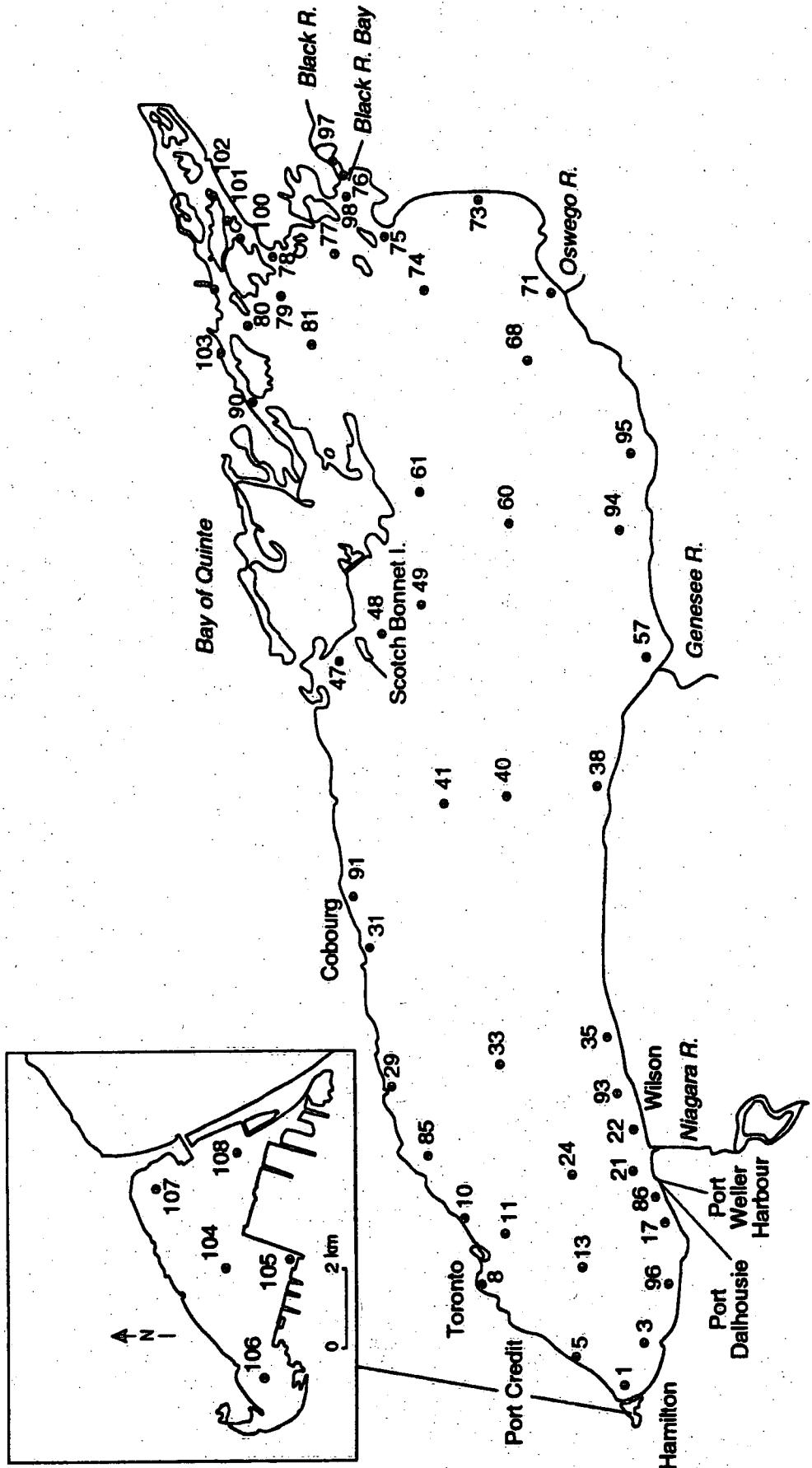


Fig. 2. Station location for Lake Ontario and Hamilton Harbour (1986 - 1990).

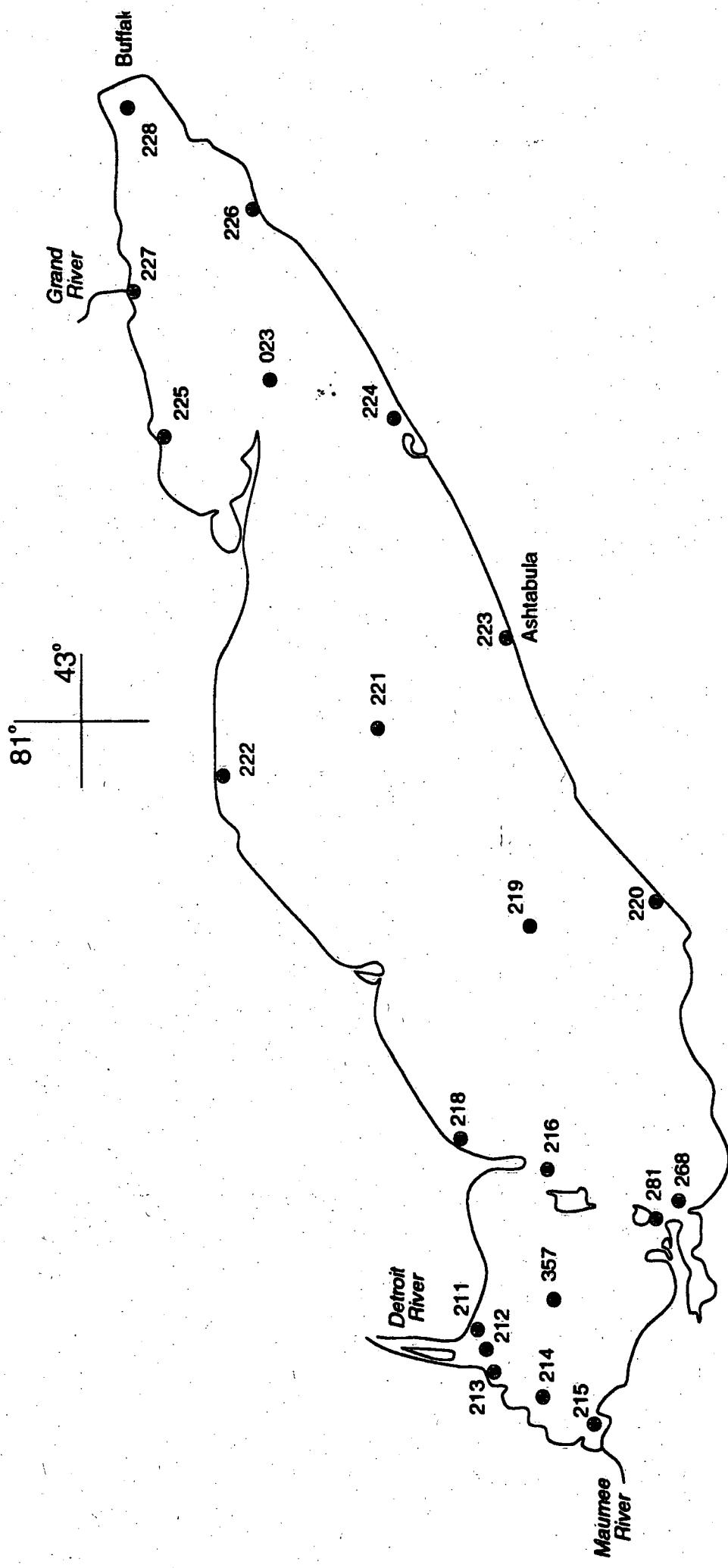


Fig. 3. Station location for Lake Erie (1986).

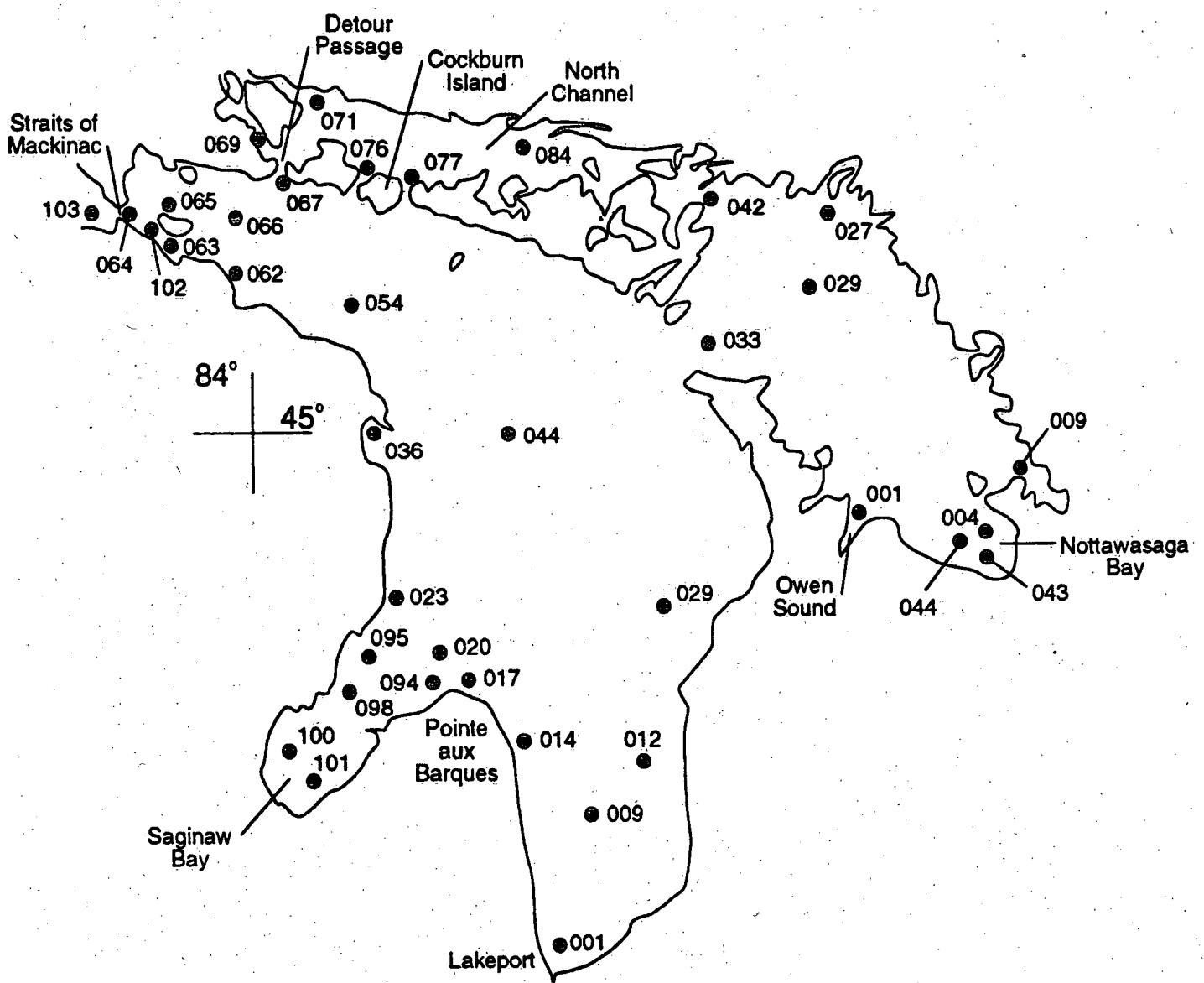


Fig. 4. Station location for Lake Huron and Georgian Bay (1986 - 1988).

APPENDIX B : SUMMARY OF RESULTS 1986-1990

| Link Superior (NFT) (ng/L) Station Number | e-BMOC | Latitude | Longitude | Altitude | Neoplastic Epithelial | Neoplastic Glandular | Neoplastic Chondroblast | Neoplastic Chondrocyte | Endothelial | Dermis | Epidermis | Pp-TME | Pp-DOT | Sulf- | Methox- | Methy- | Other | Total | 1.0-0.08 | 1.4-0.08 | 1.2-0.08 | Total | 18.11C8 | 18.11C9 | 18.11C10 | 18.11C11 | 18.11C12 | 18.11C13 | 18.11C14 | 18.11C15 | 18.11C16 | 18.11C17 | 18.11C18 | 18.11C19 | 18.11C20 | 18.11C21 | 18.11C22 | 18.11C23 | 18.11C24 | 18.11C25 | 18.11C26 | 18.11C27 | 18.11C28 | 18.11C29 | 18.11C30 | 18.11C31 | 18.11C32 | 18.11C33 | 18.11C34 | 18.11C35 | 18.11C36 | 18.11C37 | 18.11C38 | 18.11C39 | 18.11C40 | 18.11C41 | 18.11C42 | 18.11C43 | 18.11C44 | 18.11C45 | 18.11C46 | 18.11C47 | 18.11C48 | 18.11C49 | 18.11C50 | 18.11C51 | 18.11C52 | 18.11C53 | 18.11C54 | 18.11C55 | 18.11C56 | 18.11C57 | 18.11C58 | 18.11C59 | 18.11C60 | 18.11C61 | 18.11C62 | 18.11C63 | 18.11C64 | 18.11C65 | 18.11C66 | 18.11C67 | 18.11C68 | 18.11C69 | 18.11C70 | 18.11C71 | 18.11C72 | 18.11C73 | 18.11C74 | 18.11C75 | 18.11C76 | 18.11C77 | 18.11C78 | 18.11C79 | 18.11C80 | 18.11C81 | 18.11C82 | 18.11C83 | 18.11C84 | 18.11C85 | 18.11C86 | 18.11C87 | 18.11C88 | 18.11C89 | 18.11C90 | 18.11C91 | 18.11C92 | 18.11C93 | 18.11C94 | 18.11C95 | 18.11C96 | 18.11C97 | 18.11C98 | 18.11C99 | 18.11C100 | 18.11C101 | 18.11C102 | 18.11C103 | 18.11C104 | 18.11C105 | 18.11C106 | 18.11C107 | 18.11C108 | 18.11C109 | 18.11C110 | 18.11C111 | 18.11C112 | 18.11C113 | 18.11C114 | 18.11C115 | 18.11C116 | 18.11C117 | 18.11C118 | 18.11C119 | 18.11C120 | 18.11C121 | 18.11C122 | 18.11C123 | 18.11C124 | 18.11C125 | 18.11C126 | 18.11C127 | 18.11C128 | 18.11C129 | 18.11C130 | 18.11C131 | 18.11C132 | 18.11C133 | 18.11C134 | 18.11C135 | 18.11C136 | 18.11C137 | 18.11C138 | 18.11C139 | 18.11C140 | 18.11C141 | 18.11C142 | 18.11C143 | 18.11C144 | 18.11C145 | 18.11C146 | 18.11C147 | 18.11C148 | 18.11C149 | 18.11C150 | 18.11C151 | 18.11C152 | 18.11C153 | 18.11C154 | 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18.11C238 | 18.11C239 | 18.11C240 | 18.11C241 | 18.11C242 | 18.11C243 | 18.11C244 | 18.11C245 | 18.11C246 | 18.11C247 | 18.11C248 | 18.11C249 | 18.11C250 | 18.11C251 | 18.11C252 | 18.11C253 | 18.11C254 | 18.11C255 | 18.11C256 | 18.11C257 | 18.11C258 | 18.11C259 | 18.11C260 | 18.11C261 | 18.11C262 | 18.11C263 | 18.11C264 | 18.11C265 | 18.11C266 | 18.11C267 | 18.11C268 | 18.11C269 | 18.11C270 | 18.11C271 | 18.11C272 | 18.11C273 | 18.11C274 | 18.11C275 | 18.11C276 | 18.11C277 | 18.11C278 | 18.11C279 | 18.11C280 | 18.11C281 | 18.11C282 | 18.11C283 | 18.11C284 | 18.11C285 | 18.11C286 | 18.11C287 | 18.11C288 | 18.11C289 | 18.11C290 | 18.11C291 | 18.11C292 | 18.11C293 | 18.11C294 | 18.11C295 | 18.11C296 | 18.11C297 | 18.11C298 | 18.11C299 | 18.11C300 | 18.11C301 | 18.11C302 | 18.11C303 | 18.11C304 | 18.11C305 | 18.11C306 | 18.11C307 | 18.11C308 | 18.11C309 | 18.11C310 | 18.11C311 | 18.11C312 | 18.11C313 | 18.11C314 | 18.11C315 | 18.11C316 | 18.11C317 | 18.11C318 | 18.11C319 | 18.11C320 | 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18.11C404 | 18.11C405 | 18.11C406 | 18.11C407 | 18.11C408 | 18.11C409 | 18.11C410 | 18.11C411 | 18.11C412 | 18.11C413 | 18.11C414 | 18.11C415 | 18.11C416 | 18.11C417 | 18.11C418 | 18.11C419 | 18.11C420 | 18.11C421 | 18.11C422 | 18.11C423 | 18.11C424 | 18.11C425 | 18.11C426 | 18.11C427 | 18.11C428 | 18.11C429 | 18.11C430 | 18.11C431 | 18.11C432 | 18.11C433 | 18.11C434 | 18.11C435 | 18.11C436 | 18.11C437 | 18.11C438 | 18.11C439 | 18.11C440 | 18.11C441 | 18.11C442 | 18.11C443 | 18.11C444 | 18.11C445 | 18.11C446 | 18.11C447 | 18.11C448 | 18.11C449 | 18.11C450 | 18.11C451 | 18.11C452 | 18.11C453 | 18.11C454 | 18.11C455 | 18.11C456 | 18.11C457 | 18.11C458 | 18.11C459 | 18.11C460 | 18.11C461 | 18.11C462 | 18.11C463 | 18.11C464 | 18.11C465 | 18.11C466 | 18.11C467 | 18.11C468 | 18.11C469 | 18.11C470 | 18.11C471 | 18.11C472 | 18.11C473 | 18.11C474 | 18.11C475 | 18.11C476 | 18.11C477 | 18.11C478 | 18.11C479 | 18.11C480 | 18.11C481 | 18.11C482 | 18.11C483 | 18.11C484 | 18.11C485 | 18.11C486 | 18.11C487 | 18.11C488 | 18.11C489 | 18.11C490 | 18.11C491 | 18.11C492 | 18.11C493 | 18.11C494 | 18.11C495 | 18.11C496 | 18.11C497 | 18.11C498 | 18.11C499 | 18.11C500 | 18.11C501 | 18.11C502 | 18.11C503 | 18.11C504 | 18.11C505 | 18.11C506 | 18.11C507 | 18.11C508 | 18.11C509 | 18.11C510 | 18.11C511 | 18.11C512 | 18.11C513 | 18.11C514 | 18.11C515 | 18.11C516 | 18.11C517 | 18.11C518 | 18.11C519 | 18.11C520 | 18.11C521 | 18.11C522 | 18.11C523 | 18.11C524 | 18.11C525 | 18.11C526 | 18.11C527 | 18.11C528 | 18.11C529 | 18.11C530 | 18.11C531 | 18.11C532 | 18.11C533 | 18.11C534 | 18.11C535 | 18.11C536 | 18.11C537 | 18.11C538 | 18.11C539 | 18.11C540 | 18.11C541 | 18.11C542 | 18.11C543 | 18.11C544 | 18.11C545 | 18.11C546 | 18.11C547 | 18.11C548 | 18.11C549 | 18.11C550 | 18.11C551 | 18.11C552 | 18.11C553 | 18.11C554 | 18.11C555 | 18.11C556 | 18.11C557 | 18.11C558 | 18.11C559 | 18.11C560 | 18.11C561 | 18.11C562 | 18.11C563 | 18.11C564 | 18.11C565 | 18.11C566 | 18.11C567 | 18.11C568 | 18.11C569 | 18.11C570 | 18.11C571 | 18.11C572 | 18.11C573 | 18.11C574 | 18.11C575 | 18.11C576 | 18.11C577 | 18.11C578 | 18.11C579 | 18.11C580 | 18.11C581 | 18.11C582 | 18.11C583 | 18.11C584 | 18.11C585 | 18.11C586 | 18.11C587 | 18.11C588 | 18.11C589 | 18.11C590 | 18.11C591 | 18.11C592 | 18.11C593 | 18.11C594 | 18.11C595 | 18.11C596 | 18.11C597 | 18.11C598 | 18.11C599 | 18.11C600 | 18.11C601 | 18.11C602 | 18.11C603 | 18.11C604 | 18.11C605 | 18.11C606 | 18.11C607 | 18.11C608 | 18.11C609 | 18.11C610 | 18.11C611 | 18.11C612 | 18.11C613 | 18.11C614 | 18.11C615 | 18.11C616 | 18.11C617 | 18.11C618 | 18.11C619 | 18.11C620 | 18.11C621 | 18.11C622 | 18.11C623 | 18.11C624 | 18.11C625 | 18.11C626 | 18.11C627 | 18.11C628 | 18.11C629 | 18.11C630 | 18.11C631 | 18.11C632 | 18.11C633 | 18.11C634 | 18.11C635 | 18.11C636 | 18.11C637 | 18.11C638 | 18.11C639 | 18.11C640 | 18.11C641 | 18.11C642 | 18.11C643 | 18.11C644 | 18.11C645 | 18.11C646 | 18.11C647 | 18.11C648 | 18.11C649 | 18.11C650 | 18.11C651 | 18.11C652 | 18.11C653 | 18.11C654 | 18.11C655 | 18.11C656 | 18.11C657 | 18.11C658 | 18.11C659 | 18.11C660 | 18.11C661 | 18.11C662 | 18.11C663 |
<th rowspan="
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |

Lake Huron 1988	Station	(ng/l)	INDENE	1234-THN	2-MTHNP	1-MTHNP	B-CLNPH	ACENPH	ACENPH	FLUORE	PHNAN	PYRENE	FLO	B(K(B)FL	BFJ	IDPY	BFH
Detection limits			0.200	0.250	0.260	0.280	0.470	0.190	0.300	0.190	0.130	0.320	0.350	0.490	0.460	0.260	0.230
Miscellaneous	12	-1.000	-1.000	-1.000	-1.000	1.510	-1.000	-1.000	-1.000	-1.000	-1.000	0.920	-1.000	-1.000	-1.000	-1.000	-1.000
Lake Huron stations	14	-1.000	-1.000	0.970	1.950	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	1.240	-1.000	-1.000	-1.000	-1.000	-1.000
Saginaw Bay and Interface with Lake Huron	62	-1.000	-1.000	-1.000	0.860	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	1.140	-1.000	-1.000	-1.000	-1.000	-1.000
Saginaw Bay and Interface with Lake Huron	66	-1.000	-1.000	1.110	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	1.000	-1.000	-1.000	-1.000	-1.000	-1.000
Saginaw Bay and Interface with Lake Huron	67	2.980	-1.000	2.340	1.910	-1.000	2.670	1.130	1.910	4.480	-1.000	4.330	-1.000	-1.000	-1.000	-1.000	-1.000
Saginaw Bay and Interface with Lake Huron	77	-1.000	-1.000	1.080	1.950	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
Saginaw Bay and Interface with Lake Huron	20	-1.000	-1.000	-1.000	1.140	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
Saginaw Bay and Interface with Lake Huron	94	-1.000	-1.000	2.000	2.380	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
Saginaw Bay and Interface with Lake Huron	96	-1.000	-1.000	-1.000	1.140	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
Saginaw Bay and Interface with Lake Huron	100	-1.000	-1.000	0.700	1.780	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	1.570	-1.000	-1.000	-1.000	-1.000	-1.000
Saginaw Bay and Interface with Lake Huron	101	-1.000	-1.000	-1.000	1.570	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	1.300	-1.000	-1.000	-1.000	-1.000	-1.000
Saginaw Bay and Interface with Lake Huron	95	-1.000	-1.000	-1.000	1.570	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	1.730	-1.000	-1.000	-1.000	-1.000	-1.000
Lake Michigan and Interface with Lake Huron	23	-1.000	-1.000	-1.000	1.570	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	1.460	-1.000	-1.000	-1.000	-1.000	-1.000
Lake Michigan and Interface with Lake Huron	63	-1.000	-1.000	-1.000	1.300	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	1.140	-1.000	-1.000	-1.000	-1.000	-1.000
Lake Michigan and Interface with Lake Huron	102	-1.000	-1.000	-1.000	1.080	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	0.810	-1.000	-1.000	-1.000	-1.000	-1.000
Lake Michigan and Interface with Lake Huron	103	-1.000	-1.000	-1.000	1.240	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	1.140	-1.000	-1.000	-1.000	-1.000	-1.000
Georgian Bay	44	-1.000	-1.000	-1.000	1.060	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	5.270	-1.000	-1.000	-1.000	-1.000	-1.000
Georgian Bay	43	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
Georgian Bay	27	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
Collingwood	4	-1.000	-1.000	-1.000	1.070	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	4.170	-1.000	-1.000	-1.000	-1.000	-1.000

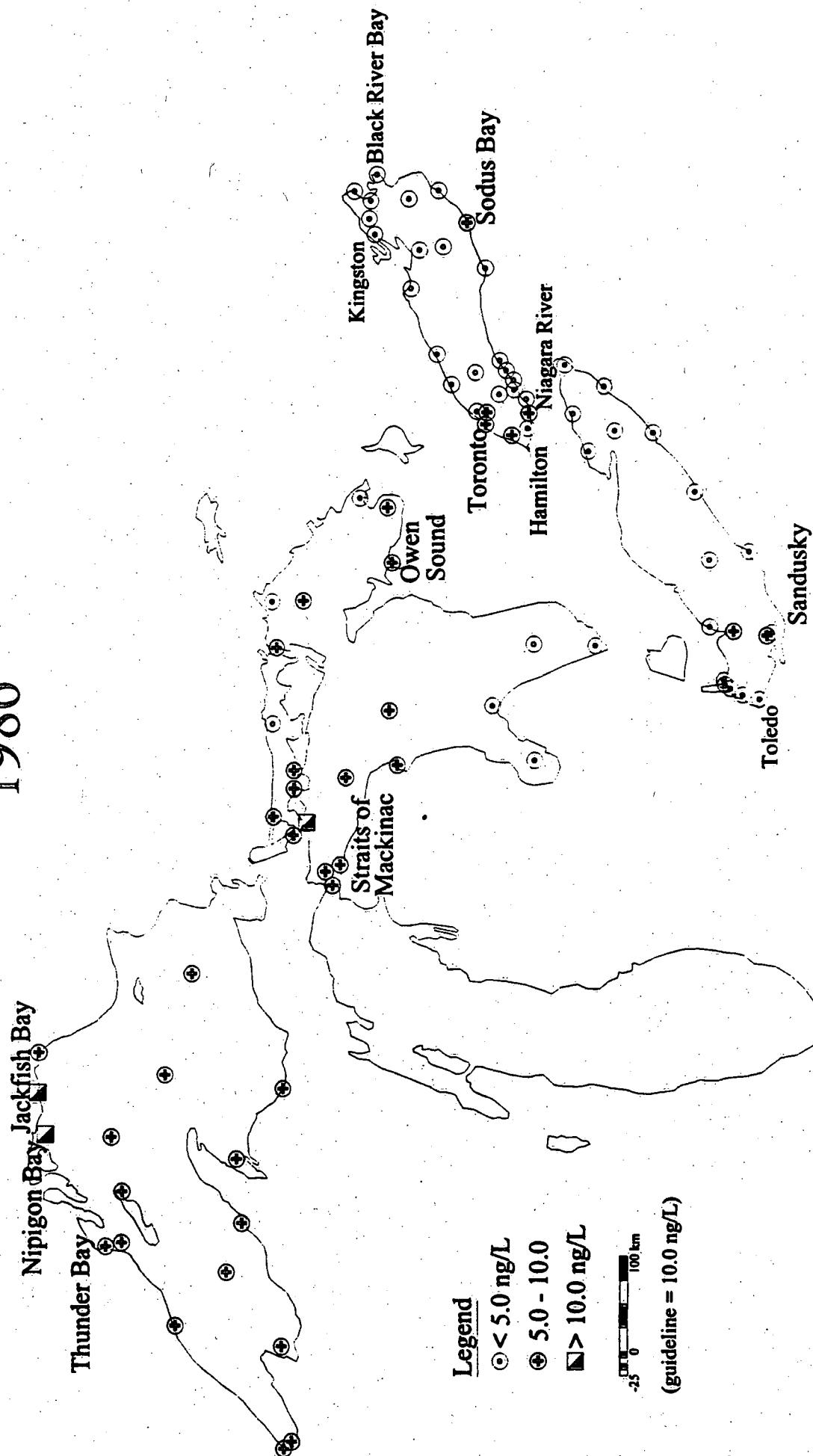
Lake Ontario (1980)	Station	(ng/L)	INDENE	1224-THNP	2-MTHNP	1-MTHNP	B-CLNPHT	ACENPH	ACENPHT	FLUORE	PHINAN	PYRENE	FLO	B(K(B)FL	BFJ	IDPY	BFH		
Detection limits		1	0.200	0.250	0.280	0.470	0.180	0.300	0.190	0.130	0.320	0.350	0.480	0.460	0.260	0.230			
1	-1.000	-1.000	1.200	-1.000	-1.000	4.187	1.200	0.501	-3.200	1.400	0.411	2.101	0.800	-1.000	0.501	0.501			
3	2.200	0.701	71.487	40.533	-1.000	1.200	0.501	-6.800	1.600	2.101	0.801	-1.000	-1.000	-1.000	-1.000	-1.000			
17	0.701	0.400	1.801	1.200	-1.000	0.301	0.501	1.600	0.501	0.800	0.501	-1.000	-1.000	-1.000	-1.000	-1.000			
98	0.800	0.301	0.701	0.501	-1.000	0.200	0.901	0.400	0.701	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000			
13	0.301	-1.000	0.301	-1.000	-1.000	-1.000	-1.000	0.600	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000			
47	0.400	0.301	0.701	0.501	-1.000	-1.000	-1.000	0.400	1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000			
61	0.400	0.301	1.000	0.901	-1.000	-1.000	-1.000	0.400	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000			
33	-1.000	-1.000	0.301	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000			
41	-1.000	-1.000	0.200	-1.000	0.501	0.400	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000			
35	0.200	-1.000	0.301	-1.000	0.701	0.501	-1.000	-1.000	0.301	0.701	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000			
63	0.301	-1.000	0.400	0.800	1.200	1.501	-1.000	0.301	-1.000	0.600	1.400	0.701	-1.000	-1.000	-1.000	-1.000			
21	0.701	0.400	1.101	0.701	-1.000	0.501	-1.000	-1.000	-1.000	0.600	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000			
57	0.200	-1.000	0.400	0.501	-1.000	-1.000	-1.000	-1.000	-1.000	0.501	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000			
74	-1.000	-1.000	0.200	-1.000	0.501	0.400	-1.000	-1.000	-1.000	0.501	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000			
90	-1.000	-1.000	0.301	-1.000	1.301	0.901	-1.000	-1.000	-1.000	0.501	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000			
61	-1.000	0.280	0.909	0.720	-1.000	-1.000	-1.000	-1.000	-1.000	0.501	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000			
103	0.389	0.451	1.381	1.280	-1.000	0.520	-1.000	-1.000	-1.000	0.789	1.560	0.548	-1.000	-1.000	-1.000	-1.000			
75	0.280	0.549	1.461	1.120	-1.000	0.301	-1.000	-1.000	-1.000	0.549	1.709	0.400	-1.000	-1.000	-1.000	-1.000			
78	0.360	0.661	1.411	1.029	-1.000	0.221	-1.000	-1.000	-1.000	0.600	1.501	-1.000	-1.000	-1.000	-1.000	-1.000			
98	-1.000	0.269	0.741	0.749	-1.000	0.240	-1.000	-1.000	-1.000	0.429	1.720	0.651	-1.000	-1.000	-1.000	-1.000			
77	-1.000	0.451	1.269	0.881	-1.000	0.260	-1.000	-1.000	-1.000	0.489	1.621	0.360	-1.000	-1.000	-1.000	-1.000			
113	0.320	0.429	1.421	1.169	-1.000	0.581	-1.000	-1.000	-1.000	0.800	2.141	0.440	-1.000	-1.000	-1.000	-1.000			
102	0.229	0.309	0.800	0.720	-1.000	0.251	-1.000	-1.000	-1.000	0.269	0.909	-1.000	-1.000	-1.000	-1.000	-1.000			
31	0.309	0.621	0.541	-1.000	0.229	-1.000	-1.000	-1.000	-1.000	3.200	1.061	0.661	-1.000	-1.000	-1.000	-1.000			
40	-1.000	0.341	0.600	0.720	-1.000	0.289	-1.000	-1.000	-1.000	0.301	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000			
60	0.281	0.331	0.669	0.709	-1.000	0.381	-1.000	-1.000	-1.000	0.621	0.440	1.011	-1.000	-1.000	-1.000	-1.000			
38	-1.000	0.261	0.621	0.629	-1.000	-1.000	-1.000	-1.000	-1.000	0.281	0.541	-1.000	-1.000	-1.000	-1.000	-1.000			
10	0.829	0.771	2.960	2.429	-1.000	0.541	-1.000	-1.000	-1.000	0.689	0.909	3.013	1.629	-1.000	-1.000	-1.000			
5	0.531	0.380	1.091	0.920	-1.000	0.429	-1.000	-1.000	-1.000	0.281	1.061	0.640	-1.000	-1.000	-1.000	-1.000			
11	0.211	0.341	0.869	0.549	-1.000	0.381	-1.000	-1.000	-1.000	0.451	-1.000	0.451	-1.000	-1.000	-1.000	-1.000			
29	0.349	0.509	0.861	0.829	-1.000	0.281	-1.000	-1.000	-1.000	0.869	0.628	1.000	-1.000	-1.000	-1.000	-1.000			
Tor-Har	8	0.629	0.389	1.481	1.291	-1.000	0.349	-1.000	-1.000	0.811	1.000	0.349	-1.000	-1.000	-1.000	-1.000	-1.000		
Black Bay R	97	1.291	1.71	5.973	4.160	-1.000	0.541	-1.000	-1.000	0.741	1.000	0.281	-1.000	-1.000	-1.000	-1.000	-1.000		
Black Bay R	76	0.440	0.651	2.081	1.681	-1.000	0.429	-1.000	-1.000	0.301	0.301	0.800	-1.000	-1.000	-1.000	-1.000	-1.000		
Niagara R	68	0.501	0.301	0.801	0.600	-1.000	0.481	-1.000	-1.000	0.781	4.427	2.800	3.627	0.611	0.571	-1.000	-1.000		
Oswego R	71	0.549	0.931	3.067	2.251	-1.000	1.291	-1.000	-1.000	1.381	1.381	4.480	2.720	4.000	-1.000	-1.000	-1.000	-1.000	
Hamilton	105	944.000	6.880	214.967	120.267	-1.000	0.811	-1.000	-1.000	1.381	134.133	298.000	114.667	202.667	28.400	29.333	12.053	21.653	
Harbour	108	95.467	2.773	33.333	20.907	0.571	45.333	30.400	84.267	178.800	193.333	304.000	318.813	36.533	14.213	-1.000	-1.000	-1.000	
106	19.467	0.680	5.120	3.440	-1.000	7.040	3.333	9.813	13.227	34.933	58.133	8.373	5.120	-1.000	-1.000	-1.000	-1.000	-1.000	
104	70.400	1.269	13.787	8.720	-1.000	20.987	6.853	25.013	33.600	57.600	93.867	18.773	13.173	10.853	-1.000	-1.000	-1.000	-1.000	
107	28.053	1.120	7.813	4.827	-1.000	10.773	4.827	-1.000	19.573	54.133	54.133	19.573	33.627	25.467	24.107	-1.000	-1.000	-1.000	-1.000

Lake Ontario PAHs 1988 (ng/L)

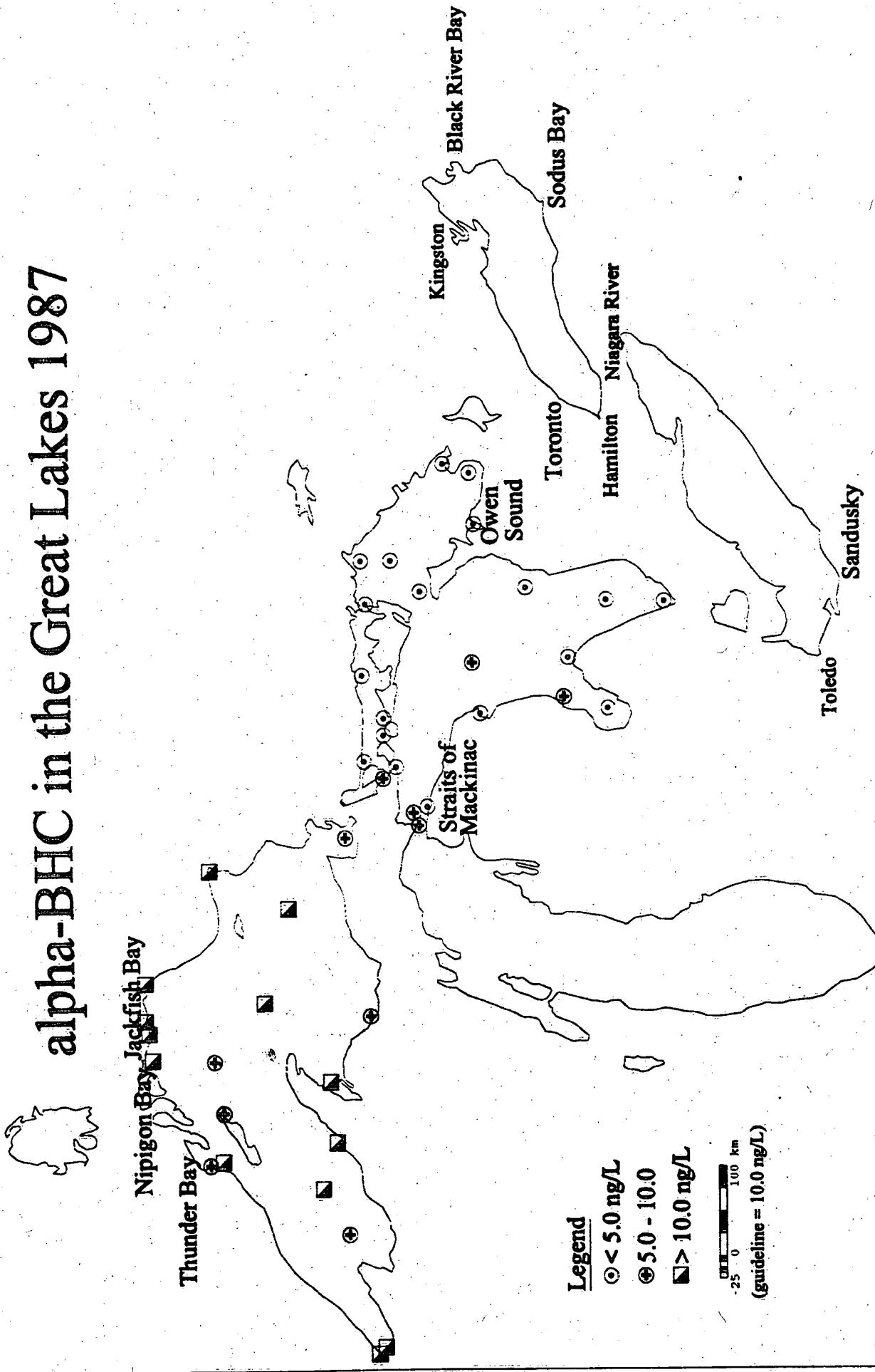
	Station	INDENE	1234-THN	2-MTHNP	1-MTHNP	B-CLNP	ACENPH	FLUORE	PHNAN	PYRENE	FLO	B(K(B)FL	BFJ	IDPY	BFH	
Detection limits		0.2	0.25	0.26	0.28	0.47	0.19	0.3	0.19	0.13	0.32	0.35	0.49	0.46	0.26	
3	-1.00	-1.00	1.12	-1.00	-1.00	-1.00	-1.00	-1.00	1.03	2.38	2.45	1.04	-1.00	-1.00	-1.00	
96	-1.00	-1.00	1.95	1.24	-1.00	0.77	1.22	1.16	2.76	5.35	7.41	3.24	-1.00	-1.00	-1.00	
22	1.49	-1.00	5.70	3.57	-1.00	-1.00	1.49	5.19	4.19	6.46	-1.00	-1.00	-1.00	-1.00	-1.00	
24	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	
33	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	
35	-1.00	-1.00	2.31	1.54	-1.00	-1.00	-1.00	-1.00	2.46	2.3	3.95	-1.00	-1.00	-1.00	-1.00	
54	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	
60	-1.00	-1.00	2.09	1.19	-1.00	-1.00	-1.00	-1.00	4.1	6.22	6.96	-1.00	-1.00	-1.00	-1.00	
95	-1.00	0.98	2.32	1.56	-1.00	-1.00	-1.00	1.19	3.99	4.84	5.01	-1.00	-1.00	-1.00	-1.00	
68	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	
74	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	1.12	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	
73	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	
78	-1.00	0.62	1.95	1.32	-1.00	0.62	1.03	3.13	6.23	5.75	11.58	-1.00	-1.00	-1.00	-1.00	
102	0.74	3.48	5.09	2.85	-1.00	-1.00	1.52	3.54	5.97	5.52	11.70	-1.00	-1.00	-1.00	-1.00	
80	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	
49	-1.00	-1.00	0.88	0.64	-1.00	-1.00	1.08	1.35	3.6	3.54	5.71	-1.00	-1.00	-1.00	-1.00	
81	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	1.66	2.45	-1.00	-1.00	-1.00	-1.00	
103	-1.00	0.94	1.08	0.89	-1.00	-1.00	-1.00	1.36	1.65	2.12	4.33	-1.00	-1.00	-1.00	-1.00	
31	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	
29	-1.00	-1.00	1.19	0.87	-1.00	-1.00	-1.00	-1.00	1.93	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	
10	-1.00	-1.00	1.17	0.99	-1.00	-1.00	-1.00	-1.00	1.83	-1.00	1.83	-1.00	-1.00	-1.00	-1.00	
11	-1.00	1.90	3.26	1.91	-1.00	-1.00	-1.00	-1.00	1.2	3.69	1.96	2.77	-1.00	-1.00	-1.00	
5	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	
Toronto Harbour	8	0.90	2.73	5.67	3.89	-1.00	0.94	1.74	2.74	9.05	8.91	12.56	-1.00	-1.00	-1.00	-1.00
Niagara River	86	1.97	1.62	6.03	4.24	-1.00	5.3	2.38	4.84	4.59	1.72	2.89	-1.00	-1.00	-1.00	-1.00
Black Bay	97	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	1.96	5.43	5.59	7.02	-1.00	-1.00	-1.00	-1.00
Black Bay	76	-1.00	-1.00	0.91	0.64	-1.00	0.55	1.29	6.16	17.18	12.38	16.54	-1.00	-1.00	-1.00	-1.00
Oswego	71	-1.00	-1.00	0.67	-1.00	-1.00	-1.00	-1.00	2.99	5.89	10.15	14	24.44	-1.00	-1.00	-1.00
Hamilton Harbour	108	64.30	-1.00	20.90	14.30	-1.00	45.7	33.5	73.8	99.5	261.6	394.69	108.1	73.20	40.50	36.80

APPENDIX C : SPATIAL DISTRIBUTION MAPS

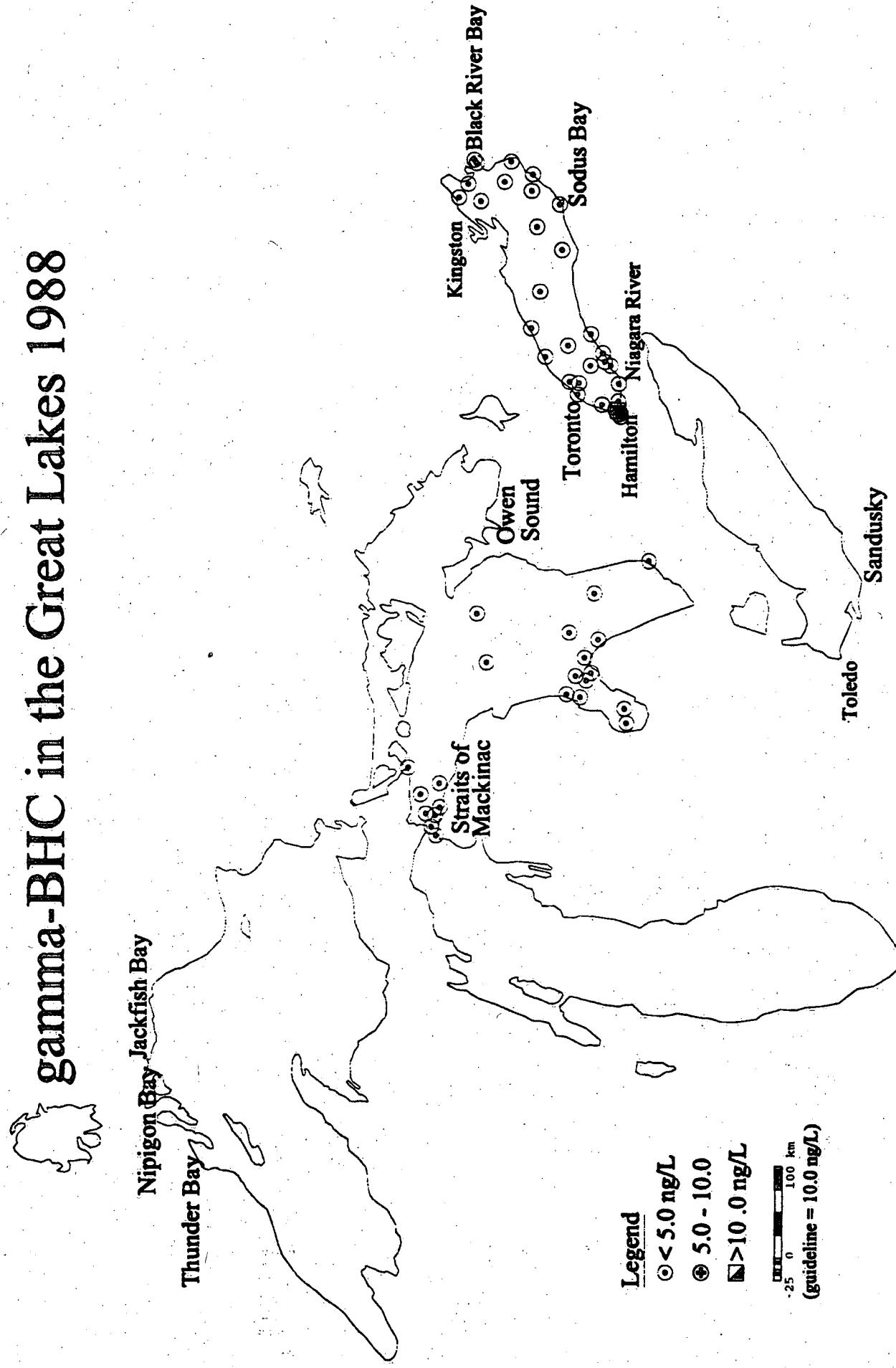
alpha-BHC Levels in the Great Lakes 1986



alpha-BHC in the Great Lakes 1987



gamma-BHC in the Great Lakes 1988



gamma-BHC in the Western Ontario 1988

Toronto

Hamilton

Niagara River

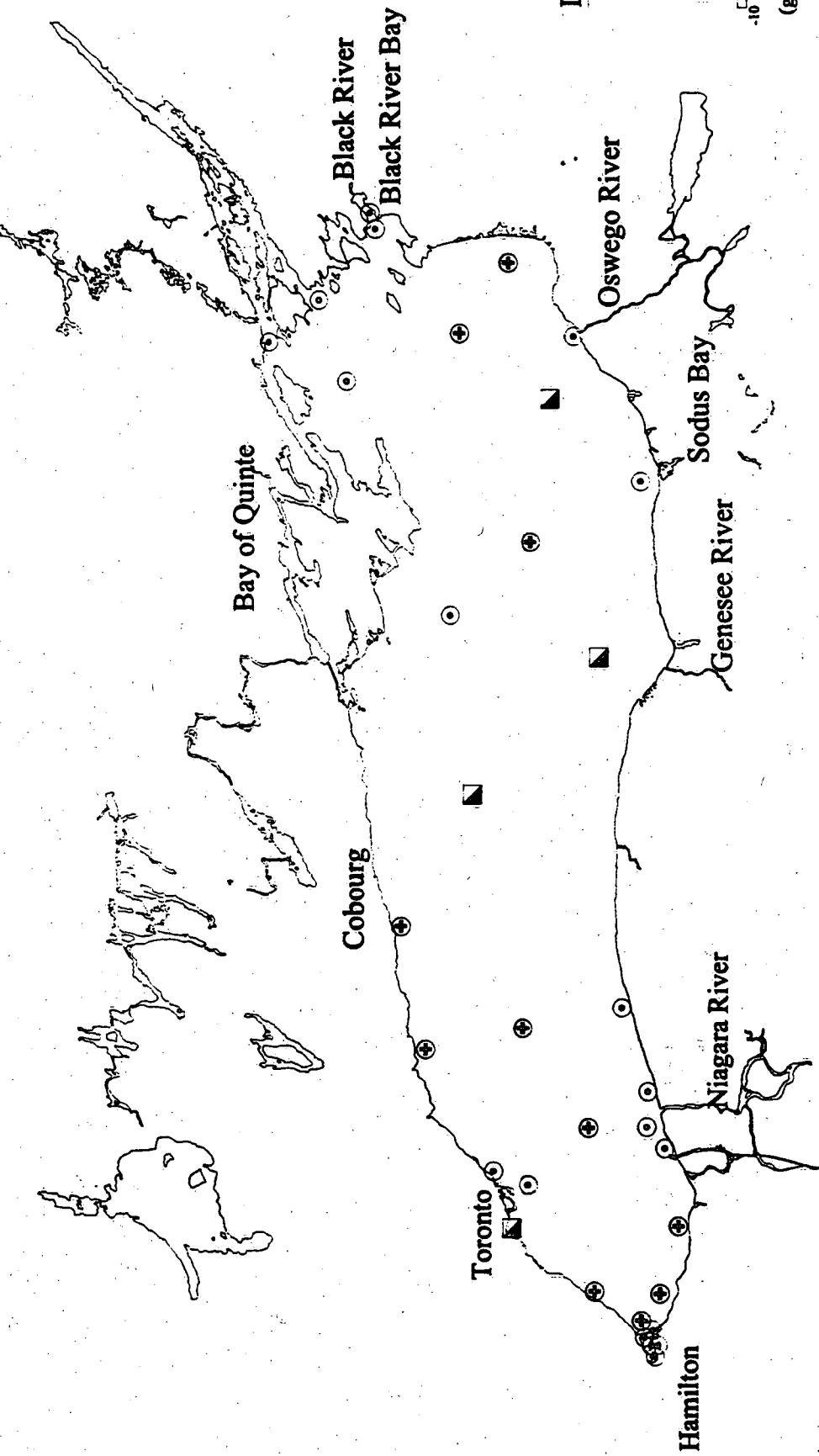
Legend

- < 5.0 ng/L
- ⊕ 5.0 - 10.0
- > 10.0 ng/L

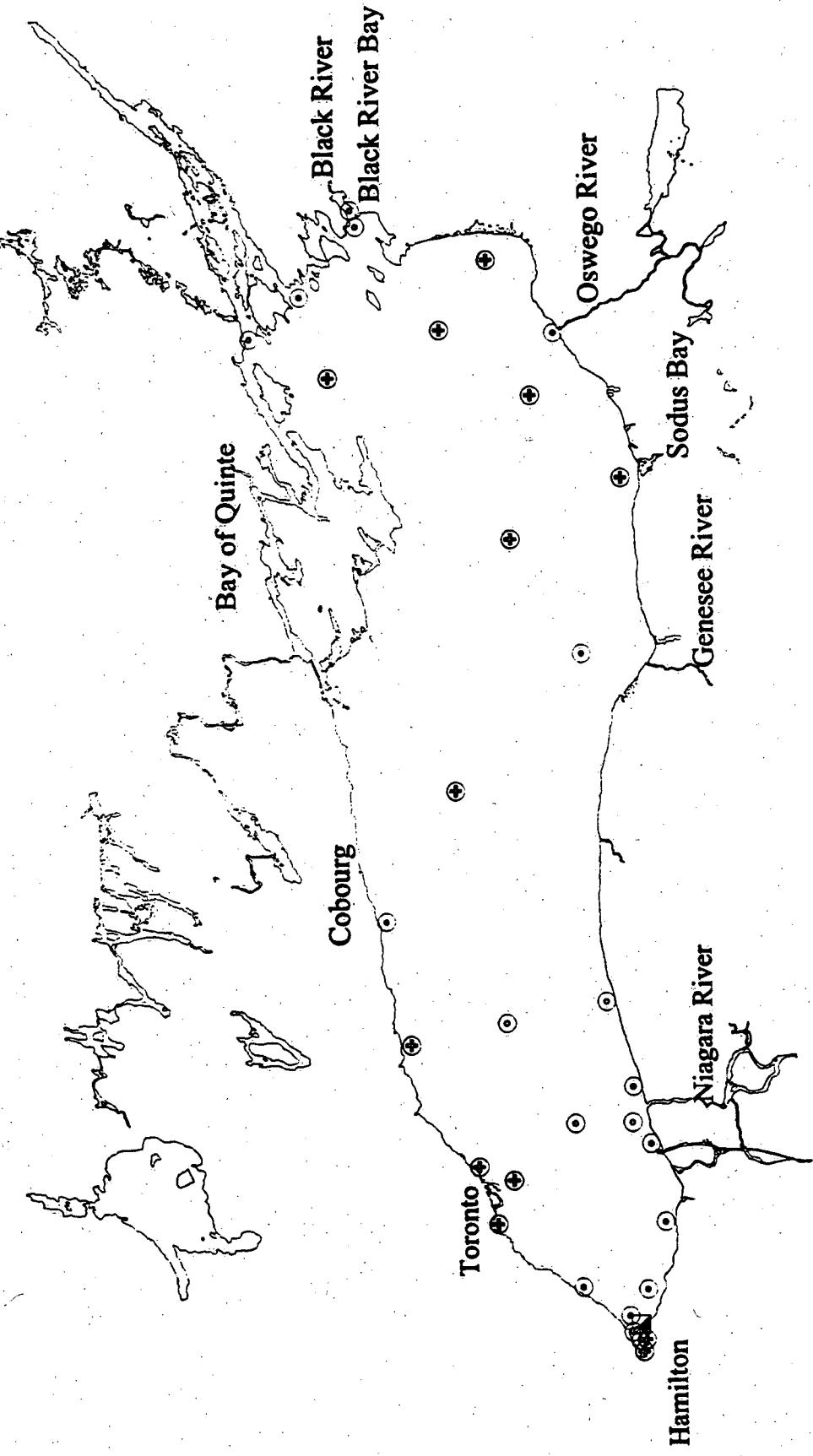
(guideline = 10.0 ng/L)



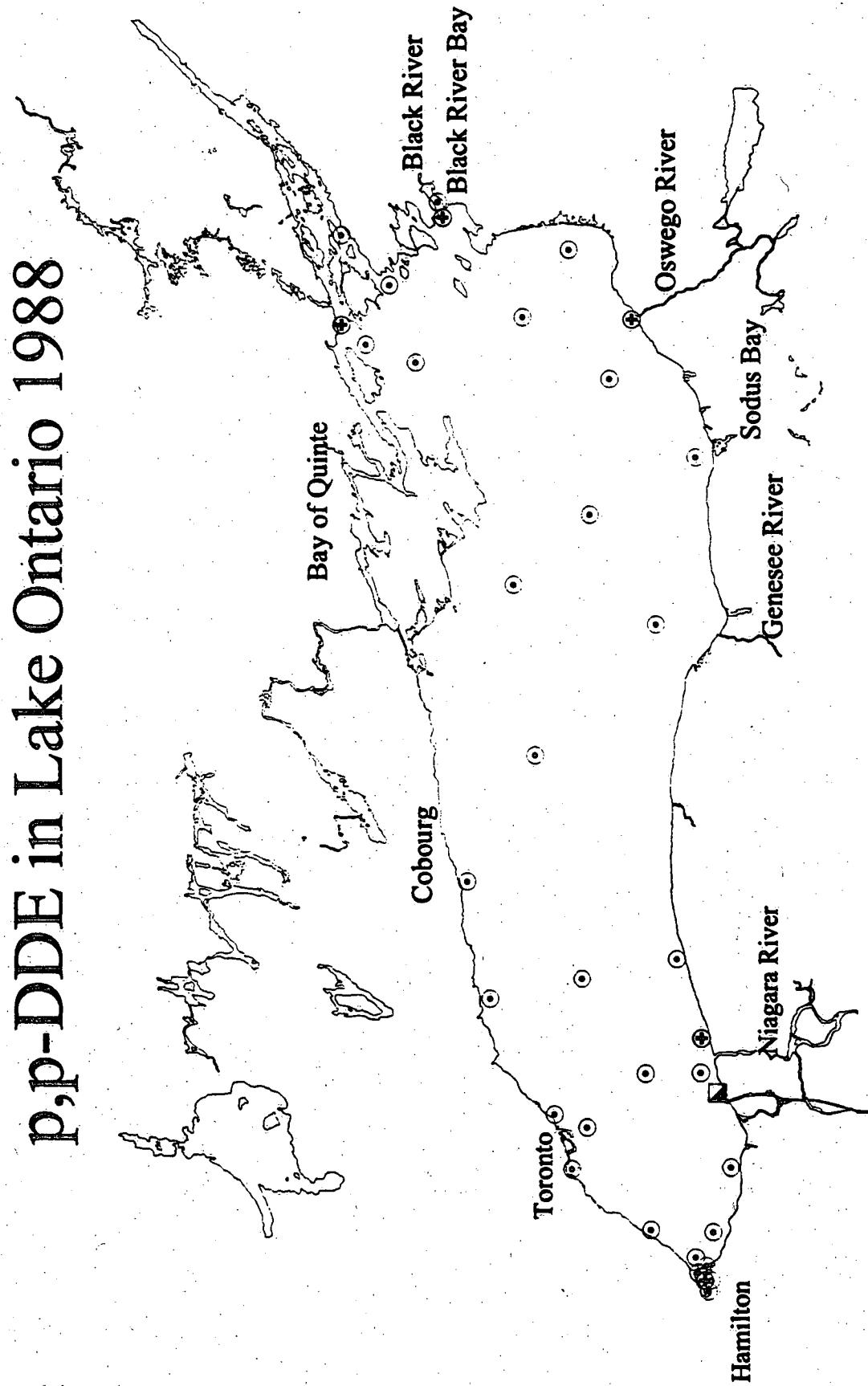
Endrin in Lake Ontario 1988



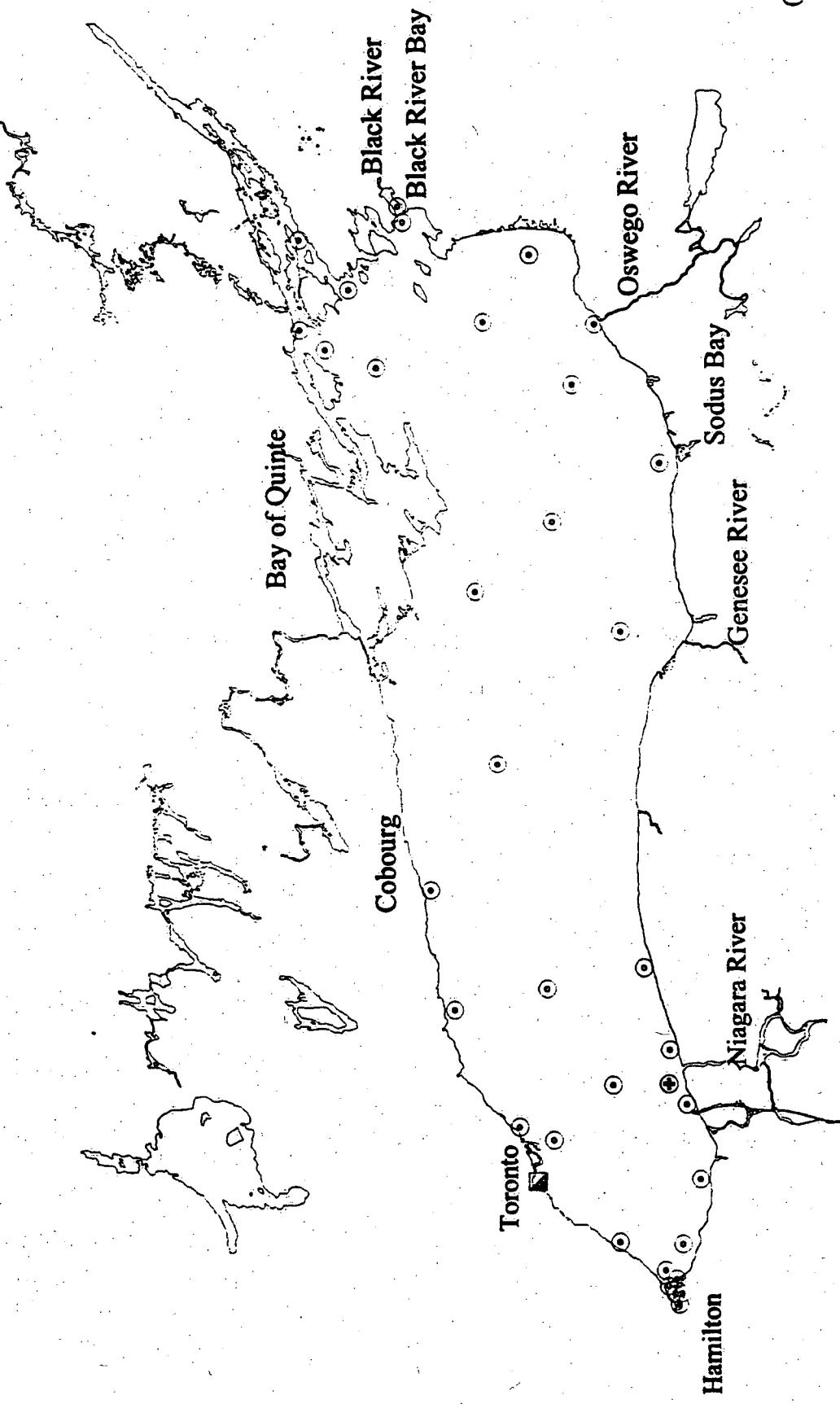
Heptachlor Epoxide in Lake Ontario 1988



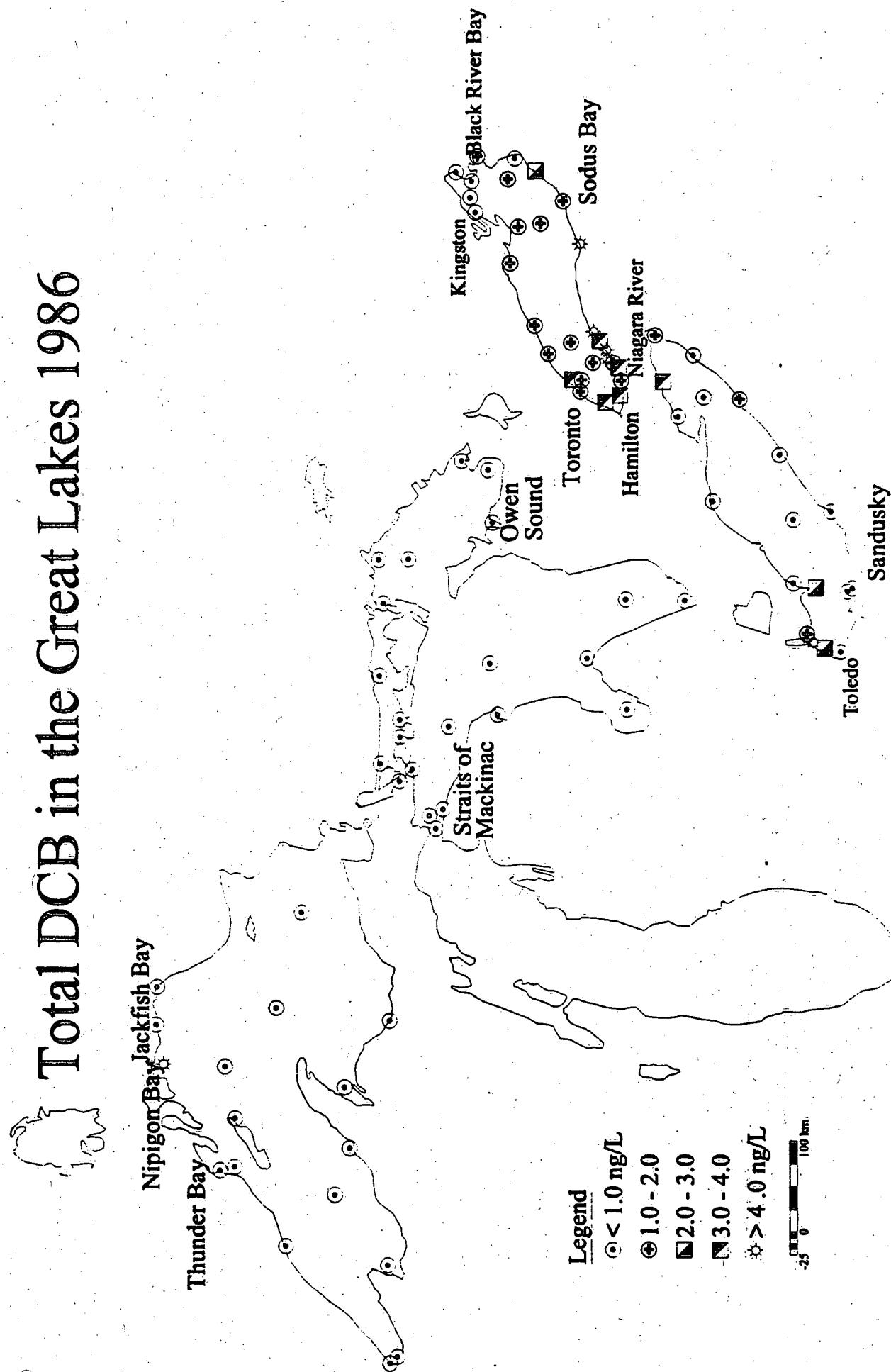
p,p -DDE in Lake Ontario 1988



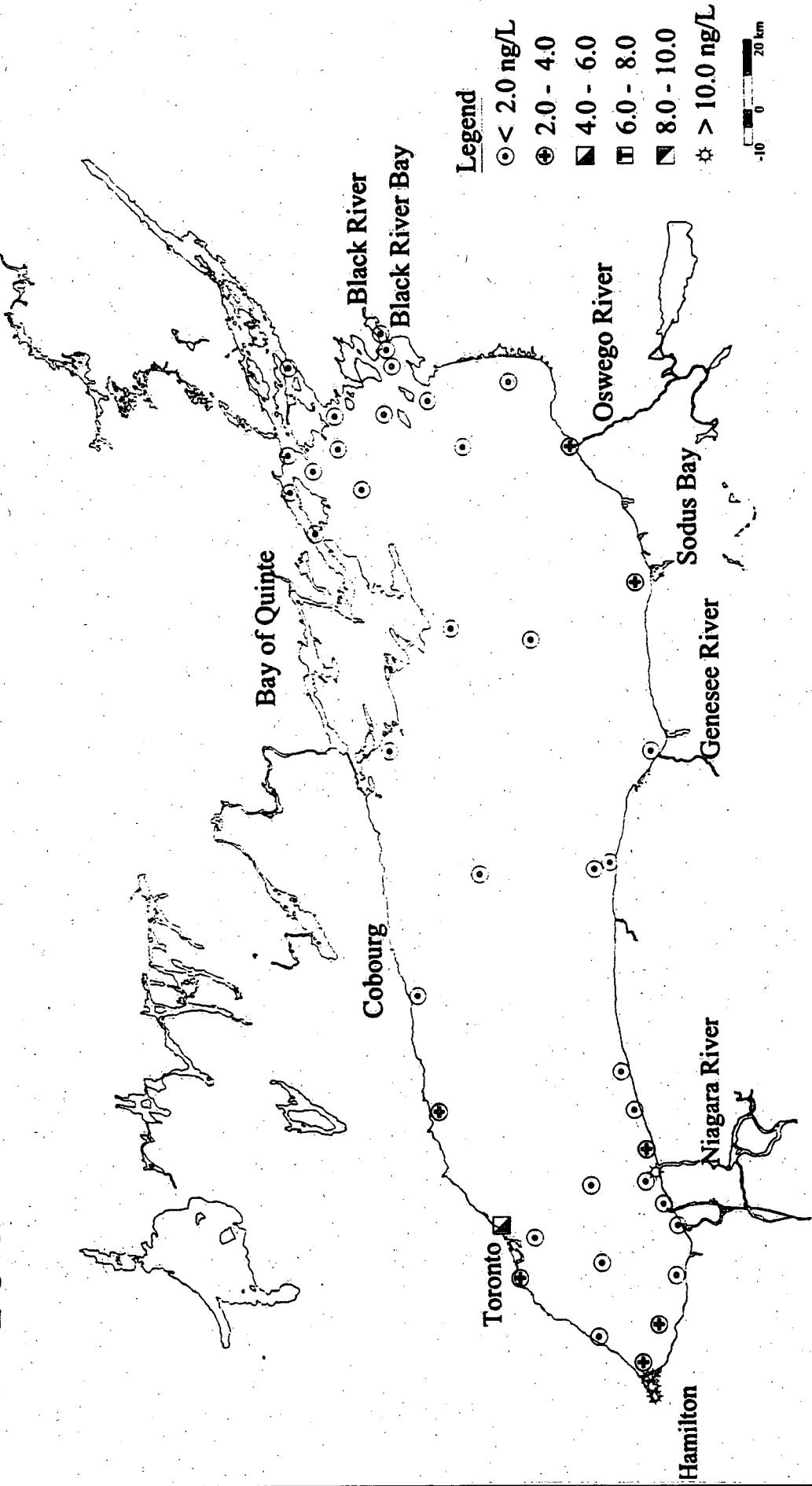
p,p-DDT Levels in Lake Ontario 1988



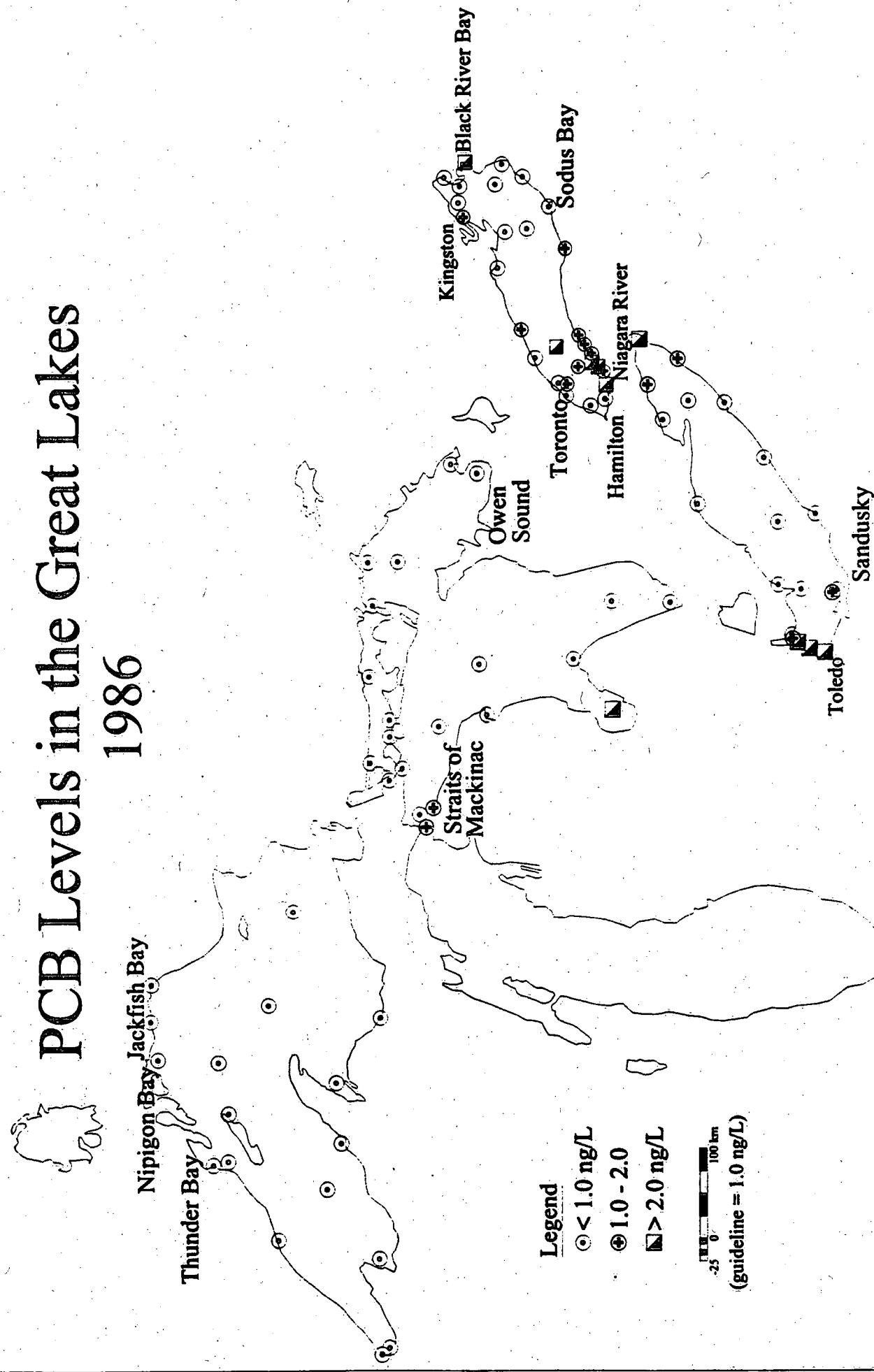
Total DCB in the Great Lakes 1986



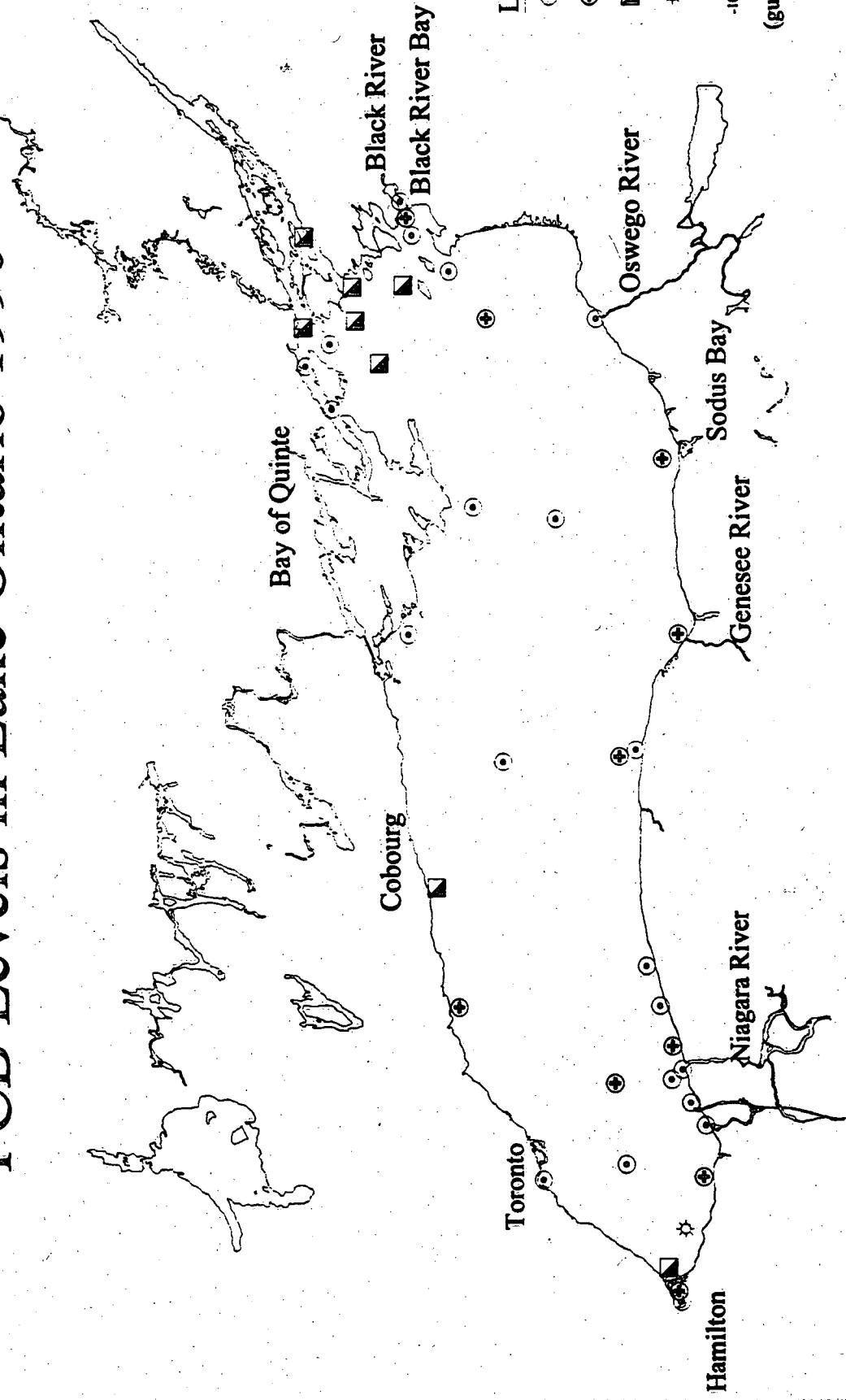
Total DCB Levels in Lake Ontario 1990



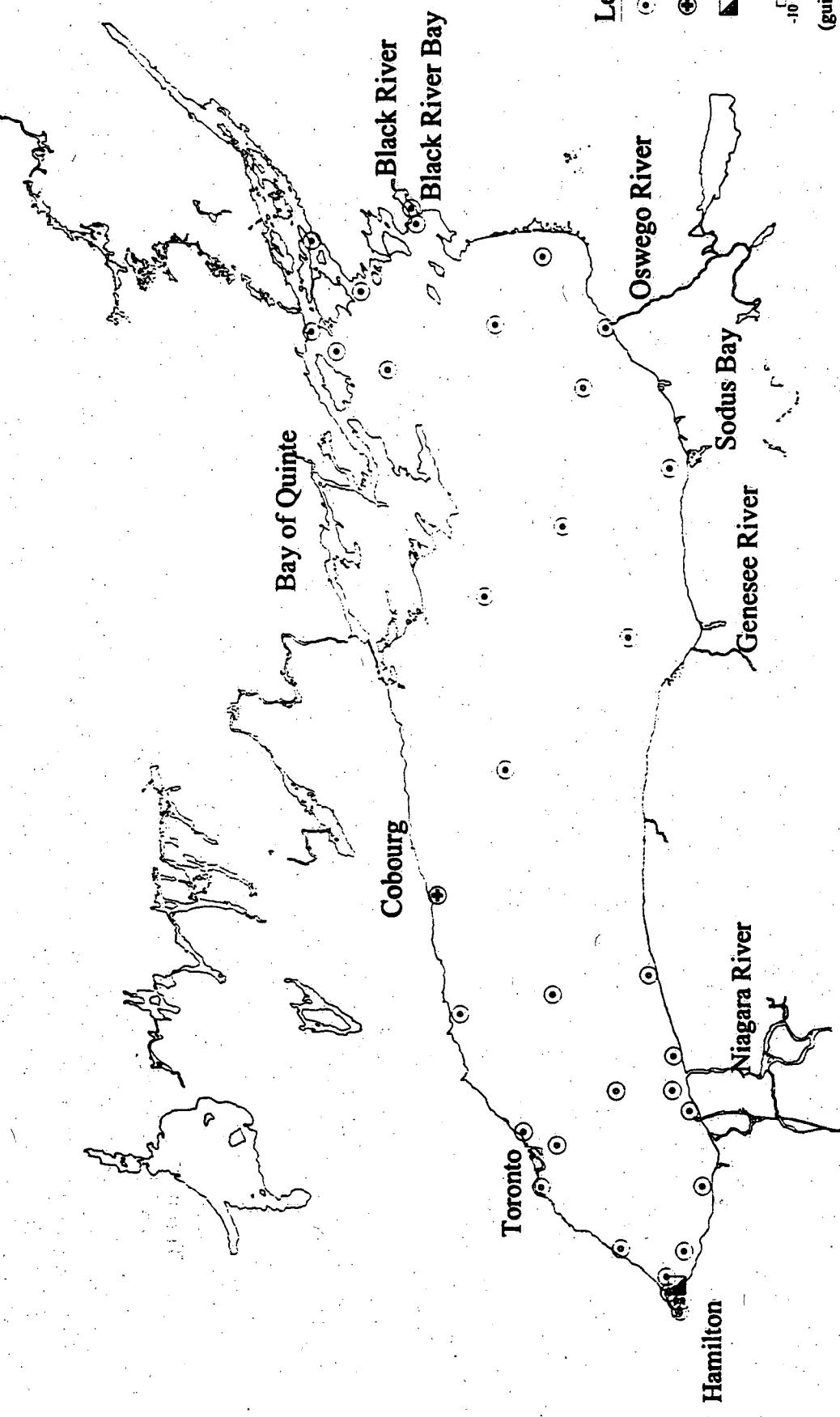
PCB Levels in the Great Lakes 1986



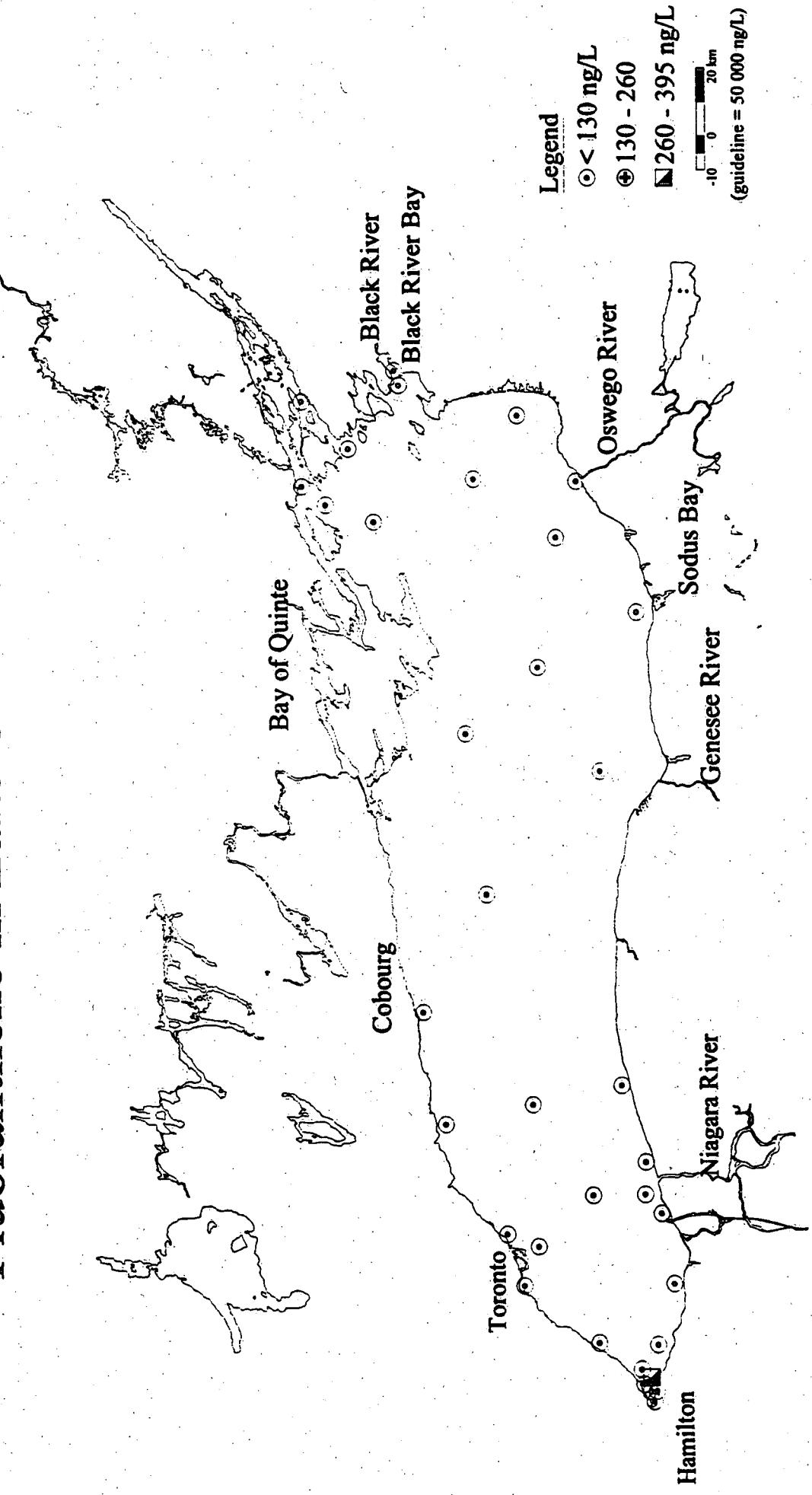
PCB Levels in Lake Ontario 1990



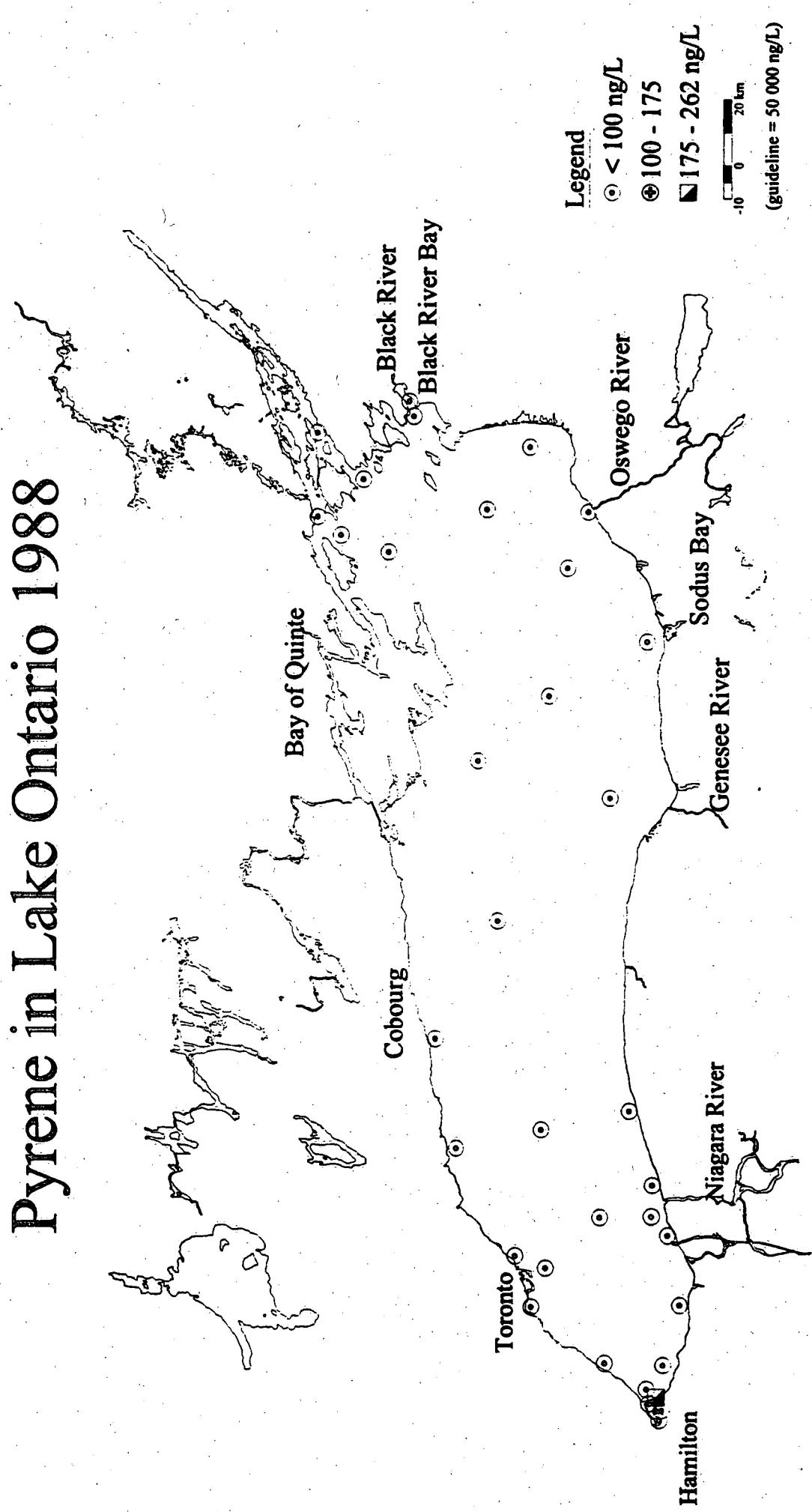
Phenanthrene in Lake Ontario 1988



Fluoranthene in Lake Ontario 1988



Pyrene in Lake Ontario 1988



APPENDIX D : SURROGATE RECOVERY RESULTS 1986-1990

Lake Erie

1986 Organics Surrogate Recoveries (%)

m+/-2SD	Fraction A				Fraction B	
	stn	dbb	tbb	tebb	tcbp	end-keto
e023		85.4	97.7	123.4	116.3	86.6
e211		66.7	74.7	77.4	76.4	46.8
e212		107.2	114.0	123.3	122.2	72.7
e213		92.3	100.6	113.9	106.1	79.8
e214		38.1	42.8	47.5	47.1	99.8
e215		118.7	135.7	163.2	123.4	55.6
e216		113.7	122.7	134.4	130.3	62.4
e218		105.5	120.1	141.7	127.6	63.8
e219		46.0	50.7	56.7	60.5	78.1
e220		38.7	48.0	63.2	75.6	71.4
e221a		71.6	75.6	76.6	77.9	104.2
e221b		107.1	109.7	119.4	122.6	112.3
e221c		45.0	50.6	54.0	59.1	74.7
e221d		101.3	110.1	122.9	117.6	113.7
e222		82.3	92.6	101.9	105.8	R 153.1
e223		34.8	37.6	39.4	44.3	108.1
e224		86.2	93.2	105.2	101.4	93.0
e225		98.8	110.1	124.8	120.7	110.0
e226		45.1	49.2	58.9	61.4	122.1
e227		114.1	123.2	146.3	129.3	105.6
e228		99.7	114.4	142.2	140.4	133.0
e268		78.2	86.5	108.9	103.8	95.4
e281		84.5	97.0	126.6	118.8	92.5
e357a		106.6	114.3	138.0	124.2	78.8
e357b		48.9	54.4	63.6	99.1	76.0
e357c		96.0	111.5	143.6	147.7	R 170.6
e357d		111.9	129.7	167.3	146.8	107.4
MEAN		82.4	91.4	106.8	103.9	95.1
S.D.		26.9	29.5	37.0	29.9	28.1
MIN		34.8	37.6	39.4	44.3	46.8
MAX		118.7	135.7	167.3	147.7	170.6
C.V.		32.6	32.3	34.6	28.7	29.5
M-2SD		28.6	32.3	32.9	44.2	38.9
M+2SD		136.1	150.5	180.8	163.6	151.3

Lake Superior

1986 Organics Surrogate Recoveries (%)

m+/-2SD	Fraction A				Fraction B		
	stn	dbb	tbb	tebb	tcbp	m+/-2SD	end-keto
	s002a	95.3	114.2	108.6	80.0		110.0
	s002b	81.2	96.6	99.6	80.6		116.9
	s002c	99.0	122.1	122.9	96.2		118.9
	s002d	96.0	121.1	125.0	94.7		101.5
	s031a	115.2	162.1	157.5	114.2		123.5
R	s031b	136.4	177.6	159.0	114.0		125.5
	s031c	126.7	168.6	153.1	104.8		111.0
R	s031d	122.4	203.3	170.9	117.6		122.1
	s089	90.5	90.0	92.0	77.9		104.3
	s100	91.4	112.6	100.8	76.2		116.8
	s105	90.7	109.5	108.9	89.9		103.8
	s113	77.7	83.4	85.7	87.7		77.0
	s130	76.2	100.7	112.5	97.3		79.7
	s139	71.4	89.4	113.2	87.4		98.6
	s140	84.0	99.8	105.3	106.1		102.2
	s177	87.9	100.1	97.3	95.8		79.7
	s221	67.9	81.3	93.1	90.7		94.1
	s220	83.8	98.5	106.0	108.3		99.2
	s196	74.0	91.0	93.4	74.1		101.2
	s169	86.4	99.6	103.3	103.8		119.8
	s164	103.4	133.6	140.4	119.5		82.7
	s080	97.3	116.4	121.4	100.9		81.7
R	s068	102.9	129.4	136.7	129.8		120.7
	s051	90.5	107.3	113.1	101.2		103.6
	s023	88.7	102.4	103.2	91.7		75.3
	MEAN	93.5	116.4	116.9	97.6		102.8
	S.D.	16.8	30.4	23.0	14.3		15.7
	MIN	67.9	81.3	85.7	74.1		75.3
	MAX	136.4	203.3	170.9	129.8		125.5
	C.V.	17.9	26.1	19.6	14.7		15.3
	M-2SD	59.9	55.6	71.0	69.0		71.4
	M+2SD	127.0	177.3	162.8	126.2		134.2

Lake Huron

1986 Organics Surrogate Recoveries (%)

m+/-2SD	Fraction A				Fraction B	
	stn	dbb	tbb	tebb	tcbp	m+/-2SD
h001		85.9	138.6	172.6	127.7	94.2
h009		87.0	113.6	128.9	111.9	94.9
h017		75.8	102.4	119.2	93.8	118.7
h101		88.2	135.5	176.4	146.5	89.3
h095a		90.7	122.0	137.2	113.9	96.8
h095b		90.8	128.4	136.6	108.6	105.1
R h095c		115.4	164.2	185.1	149.4	86.0
h095d		83.4	120.5	123.7	111.0	98.3
h029a		99.5	122.7	136.8	134.6	89.5
h029b		89.8	112.2	107.8	111.1	105.2
h029c		94.5	123.2	139.0	121.3	90.3
h029d		91.6	128.5	170.1	121.2	111.1
h040		84.8	113.0	138.9	117.3	151.4
h036		101.0	89.3	94.3	85.9	138.7
h054		81.4	102.3	125.1	105.1	R 168.7
h063		103.1	145.9	100.2	143.4	R 166.2
h064		76.8	92.3	95.2	76.7	114.3
h065		69.8	81.5	83.5	64.4	107.0
h067		114.2	90.4	96.7	76.7	123.7
h076		103.3	90.1	94.1	80.0	118.9
h077		72.0	83.9	84.8	67.9	135.5
h084		102.6	146.6	170.5	101.1	150.9
h071		110.5	87.6	105.7	88.2	128.5
h069		72.4	87.5	91.7	72.7	124.8
MEAN		91.0	113.4	125.6	105.4	117.0
S.D.		12.8	22.5	30.8	24.6	24.0
MIN		69.8	81.5	83.5	64.4	86.0
MAX		115.4	164.2	185.1	149.4	168.7
C.V.		14.1	19.9	24.5	23.3	20.5
M-2SD		65.3	68.3	64.0	56.2	68.9
M+2SD		116.7	158.5	187.2	154.6	165.1

Georgian Bay

1986 Organics Surrogate Recoveries (%)

m+/-2SD	Fraction A				Fraction B	
	stn	dbb	tbb	tebb	tcbp	end-keto
g033a	123.8	170.7	151.9	94.9		102.2
g033b	103.7	153.3	133.2	88.3		121.6
g033c	102.5	168.1	141.9	85.1		115.6
g033d	126.5	210.4	197.9	147.1	R	173.5
g009	119.5	197.3	177.4	100.6		130.6
R g001	148.3	253.8	243.8	151.9		114.5
g004	124.7	195.5	180.7	105.5		93.7
g027	95.3	138.4	158.0	85.3		108.8
g029	125.1	199.3	198.1	112.3		98.6
g042	96.4	151.3	159.1	79.8		95.3
MEAN	116.6	183.8	174.2	105.1		115.4
S.D.	15.9	32.6	31.2	24.2		22.4
MIN	95.3	138.4	133.2	79.8		93.7
MAX	148.3	253.8	243.8	151.9		173.5
C.V.	13.6	17.7	17.9	23.0		19.4
M-2SD	84.8	118.6	111.8	56.7		70.6
M+2SD	148.4	249.0	236.6	153.4		160.3

Lake Ontario

1986 Organics Surrogate Recoveries (%)

m+/-2SD	Fraction A					Fraction B	
	stn	dbb	tbb	tebb	tcgp	m+/-2SD	end-keto
o001a		98.2	93.4	91.9	90.8		77.8
o003		94.8	94.4	109.1			91.3
o005		102.9	111.1	115.6	116.6		109.9
o008		92.0	104.5	113.5	113.1		91.8
o010		109.1	119.9	128.4	124.1		82.9
o011		99.8	108.5	121.8	125.3		83.6
o017		99.4	114.9	127.9	122.1		94.1
o021		111.0	126.6	133.0	117.6		107.4
o022		111.4	133.0	124.4	112.1		78.2
o024		123.8	138.1	142.9	128.2		85.8
o029		100.4	87.7	108.2	97.1		75.9
o031		103.2	113.8	105.1	92.8		88.1
o035		92.3	100.8	97.1	103.7		80.4
o041a		86.5	91.2	86.9	97.1		126.5
o041b		110.2	116.5	130.6	128.7		85.1
o041c		91.5	112.6	103.5	115.1		95.4
o041d		86.6	80.1	87.4	96.6		64.8
o047		90.5	99.0	119.4	110.8		67.9
o057		78.3	85.6	105.3	95.3		109.1
o060		84.0	88.7	102.8	102.6		89.3
o061		89.2	96.1	113.4	109.3		121.8
o071		88.6	97.2	122.6	108.5		105.9
R o073		36.3	38.7	43.1	48.0	R	50.5
o074		94.4	99.3	111.5	107.6		83.1
o076		93.4	105.8	136.3	116.5		67.1
R o078		28.1	28.9	31.9	35.8		101.4
o080		91.1	100.7	115.3	125.1		104.7
o081a		89.0	93.0	91.3	115.0		99.9
o081b		88.7	91.3	96.0	110.3		76.4
o081c		91.1	113.1	142.4	156.0		82.5
o081d		83.5	88.5	99.4	109.0		87.4
o086		92.0	111.3	133.7	131.8		96.6
o090		80.7	83.0	88.2	83.7		78.8
o093		68.3	84.2	87.9	124.3		93.6
o095		79.2	93.4	103.4	142.8		108.6
o096		89.2	107.7	112.2	138.7	R	143.0
o102		86.0	98.9	106.2	140.9		86.8

MEAN	90.1	98.7	107.8	110.9	91.2
S.D.	17.4	20.6	22.9	22.9	17.8
MIN	28.1	28.9	31.9	35.8	50.5
MAX	123.8	138.1	142.9	156.0	143.0
C.V.	19.3	20.9	21.3	20.6	19.5
M-2SD	55.3	57.4	62.0	65.1	55.7
M+2SD	125.0	139.9	153.7	156.7	126.7

Lake Superior

1987 Organics Surrogate Recoveries (%)

m+/-2SD	stn	Fraction A				Fraction B	
		dbb	tbb	tebb	tcbp	end-keto	d-bhc
R	2	121.8	99.2	101.8	142.4	141.0	85.5
R	31	136.4	101.4	116.0	154.4	125.0	87.3
	89	107.8	100.8	110.6	124.8	119.0	100.0
	100	101.8	103.6	119.4	122.8	133.0	99.2
R	101	92.0	109.2	125.2	110.0	119.0	117.0
	105	104.0	115.0	153.2	141.8	114.0	102.0
	113	119.0	101.0	121.8	130.2	106.0	107.0
	130	105.8	94.0	113.8	124.4	126.0	124.0
R	139	72.4	96.4	144.0	147.2	136.0	89.9
	140	102.2	100.8	133.4	147.2	93.3	81.4
	177	115.0	110.8	124.4	129.6	R	151.0
	221	116.4	104.6	146.2	138.4		131.0
	220	91.6	87.4	128.4	125.4		96.7
	187	94.2	105.2	132.2	154.6		118.0
	196	92.6	93.2	132.2	144.6	R	117.0
	169	108.8	102.4	140.0	158.6		102.0
	164	103.2	104.4	132.6	155.6		112.0
	80	110.6	96.8	148.6	166.0		103.0
	68	99.0	98.4	133.8	139.6		92.9
R	52	71.8	77.6	119.0	147.8		86.0
	23	107.6	105.2	149.8	168.0		80.8
	MEAN	103.5	100.4	129.8	141.6		115.0
	S.D.	14.7	7.9	13.6	15.0		103.0
	MIN	71.8	77.6	101.8	110.0		92.9
	MAX	136.4	115.0	153.2	168.0		127.4
	C.V.	14.2	7.9	10.4	10.6		86.0
	M-2SD	74.1	84.6	102.7	111.7		80.8
	M+2SD	133.0	116.2	157.0	171.5		131.0

Lake Huron

1987 Organics Surrogate Recoveries (%)

m+/-2SD	Fraction A					Fraction B		
	stn	dbb	tbb	tebb	tcbp	m+/-2SD	end-keto	d-bhc
	9	90.0	69.6	91.0	108.0		92.6	86.3
	17	94.4	71.4	97.6	123.2		122.0	143.0
R	95	103.2	103.2	118.2	83.4		138.0	163.0
	29	104.4	104.4	103.0	119.0		131.0	128.0
	44	104.2	104.2	109.4	109.8		108.0	119.0
	36	105.2	105.2	107.0	142.0		119.0	167.0
	63	97.8	97.8	90.8	114.4		130.0	108.0
	64	99.2	99.2	118.8	117.6		151.0	175.0
	65	114.0	114.0	106.0	146.4		109.0	113.0
	67	106.6	106.6	102.6	130.0		152.0	170.0
	76	128.0	80.8	103.4	110.8		91.6	81.7
R	77	131.0	93.0	119.6	126.4		114.0	95.1
	84	112.0	79.2	121.4	96.4		102.0	70.5
	71	106.0	64.6	101.4	106.0		123.0	113.0
	69	111.0	70.2	84.6	135.8		117.0	109.0
	MEAN	107.1	90.9	105.0	117.9		120.0	122.8
	S.D.	10.7	15.9	10.8	16.3		17.8	32.8
	MIN	90.0	64.6	84.6	83.4		91.6	70.5
	MAX	131.0	114.0	121.4	146.4		152.0	175.0
	C.V.	10.0	17.5	10.3	13.8		14.8	26.7
	M-2SD	85.6	59.0	83.3	85.4		84.5	57.3
	M+2SD	128.6	122.8	126.7	150.5		155.5	188.3

Georgian Bay

1987 Organics Surrogate Recoveries (%)

		Fraction A				Fraction B	
m+/-2SD		stn	dbb	tbb	tebb	tcbp	m+/-2SD
		33	115.0	72.0	106.6	135.8	96.2
		1	114.0	80.0	113.6	132.4	106.0
		4	109.0	83.8	120.6	131.8	109.0
		9	108.0	66.8	85.8	96.0	93.0
		29	113.0	73.6	83.4	80.6	100.0
		27	87.2	62.8	84.0	86.2	116.0
R	42		149.0	104.6	135.2	109.8	98.1
	MEAN		113.6	77.7	104.2	110.4	102.6
	S.D.		16.9	12.9	18.9	21.6	7.5
	MIN		87.2	62.8	83.4	80.6	93.0
	MAX		149.0	104.6	135.2	135.8	116.0
	C.V.		14.9	16.5	18.2	19.6	7.3
	M-2SD		79.8	52.0	66.3	67.2	87.6
	M+2SD		147.4	103.4	142.0	153.6	117.6
							119.8

Lake Huron

1988 Organics Surrogate recoveries (%)

m+/-2sd	stn	Fraction A			Fraction B	
		dbb	tbb	tebb	m+/-2sd	end-keto
	12	106				115
R	14	94	75	58		88
	62	90	70	74		86
	66	90	71	90		117
	67	85	67	84		105
	67	104	79	102		124
R	17	82	71	112		94
	20	100	90	90		82
	94	96	92	88		103
	96	84	76	78		83
	100	80	70	72		87
	100	90	88	82		98
	101	84	75	77		95
	95	74	64	69	R	120
	23	78	70	76		98
	23	78	78	82		98
	63	92	74	82		82
	102	82	80	84	R	115
	103	104	88	95		101
	65	81	64	89		120
R	64	120	85	110		123
	44	105	79	65		110
	43	101	65	88		125
	27	103	85	92		105
	27	94	72	95		92
	4	110	69	87		107
	4	101	83	85		115
MEAN		92.9	76.2	84.8		103.3
S.D.		11.4	8.1	12.2		13.6
MIN		74.0	64.0	58.0		82.0
MAX		120.0	92.0	112.0		125.0
C.V.		12.2	10.6	14.4		13.2
M-2SD		70.2	59.9	60.4		76.0
M+2SD		115.6	92.4	109.3		130.5
						120.5

Lake Ontario

1988 Organics Surrogate recoveries (%)

m+/-2sd	Fraction A				Fraction B		
	stn	dbb	tbb	tebb	m+/-2sd	end-keto	d-bhc
	78	91.0	84.8	97.6		100.0	103.0
	80	99.0	81.3	87.8	R		214.1
	81	84.0	66.1	76.2		113.0	112.5
	103	106.0	80.9	101.1		103.0	114.8
	102	93.6	59.2	72.8	R	152.0	156.0
	49	85.0	77.8	86.9	R		219.1
R	73	133.0	106.7	113.9		139.0	138.5
	74	106.0	98.4	117.0		143.0	122.0
	95	106.0	71.2	91.2		87.3	108.0
	22	101.0	96.0	114.0		126.0	160.0
	35	85.0	79.0	87.0		86.0	93.0
	35A	100.0	72.0	88.0		115.0	109.0
	1	102.0	71.0	96.0		103.0	88.0
	3	87.0	88.0	90.0		88.0	84.0
R	5	124.0	97.6	126.0		106.0	106.0
	10	86.0	85.0	94.4		119.0	147.4
	21	93.0	74.0	78.0		112.0	161.0
	96	96.0	71.0	98.0		104.0	71.0
	11	110.0	78.4	92.8			
	11A	101.0	96.8	106.0		110.0	164.0
	24	108.0	100.0	107.0		120.0	136.0
	29	96.0	66.1	78.9		139.0	191.4
R	31	100.0	109.0	121.3		77.4	125.6
	33	76.0	77.0	94.0		111.0	110.0
	41	103.0	71.0	97.0		144.0	123.0
	54	97.0	89.0	115.0		114.0	119.0
	60	122.0	84.8	109.0		124.0	87.6
	68	126.0	92.8	106.0			
	104	95.0	72.0	89.0		114.0	80.0
	104A	98.0	70.0	89.0		90.0	82.0
	105	63.0	57.0	101.0		109.0	65.0
	105A	68.0	65.0	93.0		96.0	111.0
	106	72.0	69.0	93.0		121.0	68.0
R	107	43.0	90.0	116.0		103.0	125.0
	108	87.0	89.0	95.0		108.0	73.0
	8	104.0	75.2	94.4			
	86	72.0	82.0	91.0		83.0	87.0

76	94.6	67.2	82.4	99.9	96.8
97	84.0	71.2	94.4	96.0	97.2
71	108.0	68.8	81.6	134.0	88.8
MEAN	95.1	80.0	96.6	111.1	117.2
S.D.	17.2	12.6	12.6	18.2	37.9
MIN	43.0	57.0	72.8	77.4	65.0
MAX	133.0	109.0	126.0	152.0	219.1
C.V.	18.1	15.8	13.1	16.4	32.3
M-2SD	60.8	54.7	71.3	74.7	41.5
M+2SD	129.5	105.3	121.8	147.6	193.0

Lake Ontario

1990 Organics Surrogate Recoveries

m+/-2SD	Fraction A				Fraction B		
	stn	dbb	tbb	tebb	m+/-2SD	d-bhc	end-keto
	77	63.3	67.3	109.4		122.0	85.7
	78	46.2	64.7	106.3		91.9	67.5
	79	97.1	77.9	107.5		113.3	103.1
	98	58.4	68.8	114.6		87.6	87.9
	80	95.6	76.1	107.7		87.6	77.4
	81	61.1	79.0	136.1		100.7	81.7
	81A	55.3	69.6	120.5		92.5	80.7
	113	69.1	70.9	79.6		127.9	175.0
	103	57.6	71.6	128.3	R	174.7	96.5
	102	86.6	75.2	104.7		101.1	133.5
R	73	68.8	58.5	67.4		84.0	86.7
	57	59.2	79.5	86.0		92.5	87.3
	75	52.8	79.1	133.5		117.6	82.3
	74	59.5	75.6	88.9		106.0	95.2
	90	63.5	106.8	121.0		81.7	77.1
	95	95.4	78.3	99.9		78.3	119.8
	22	107.3	95.5	112.8		120.3	106.4
	35	104.3	88.8	107.7		115.4	93.0
	93	96.3	80.8	93.7		100.0	102.2
	1	93.9	109.6	113.5		88.6	113.4
	3	84.4	108.5	124.3		101.8	94.3
	17	90.2	78.0	112.9		56.0	90.7
R	5	89.5	94.8	159.8		99.6	110.9
R	10	92.4	124.9	130.5		100.2	149.2
	21	64.4	94.0	99.7		131.3	92.6
	13	69.3	77.7	128.8		100.4	95.2
	47	71.6	82.1	124.1		64.2	90.1
	61	71.9	80.0	122.5		75.4	99.0
	96	81.5	74.5	113.6		83.1	90.5
R	11	91.9	116.0	158.7		82.9	89.1
	24	96.0	91.5	99.4		120.3	120.3
	29	77.7	79.8	129.5		77.0	113.8
	31	82.5	80.1	92.3		70.1	125.2
	38	98.0	110.9	126.5		77.8	121.5
	33	102.5	89.6	100.8		115.9	111.4
	41	65.7	67.5	106.0		88.8	97.7
	40	89.5	89.1	102.1		72.6	126.3

41A	84.2	88.2	132.2		93.4	91.2
60	79.9	75.1	85.1		83.7	118.1
60A	91.0	99.2	106.2		89.4	94.6
104	85.4	101.1	154.4	R	303.0	345.5
105	79.9	81.5	146.2		90.9	121.8
106	86.6	82.9	120.0		85.4	109.1
107	74.4	86.7	116.7		49.4	60.7
R	108	56.1	115.4	172.3		91.0
	8	77.6	97.6	105.0		73.5
R	86	87.3	49.4	74.0		45.2
	76	61.6	83.1	131.9		87.4
R	97	41.8	54.2	126.0		108.8
	71	82.1	116.2	86.9		79.2
MEAN	78.0	84.9	114.6		97.6	107.2
S.D.	16.1	16.4	21.7		36.7	39.9
MIN	41.8	49.4	67.4		45.2	60.7
MAX	107.3	124.9	172.3		303.0	345.5
C.V.	20.6	19.4	19.0		37.6	37.2
M-2SD	45.8	52.0	71.1		24.3	27.4
M+2SD	110.1	117.7	158.0		170.9	187.0

R 1364

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